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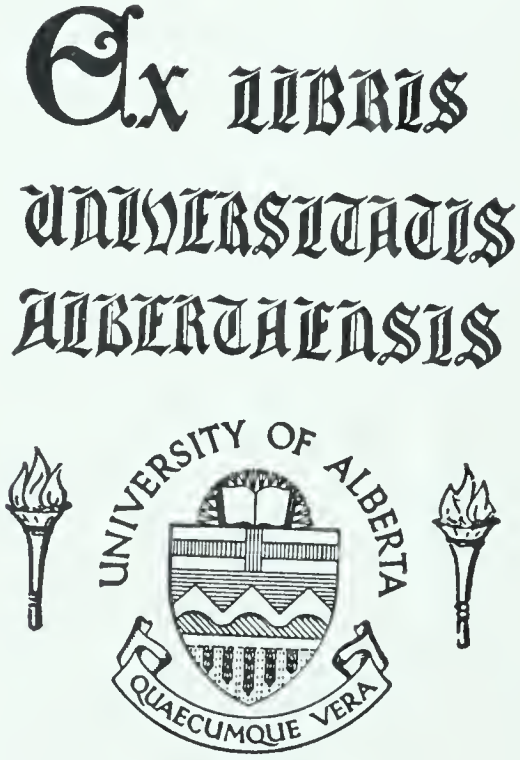

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A MULTISENSORY APPROACH TO THE LEARNING OF SYMBOLS

A THESIS PRESENTED TO THE

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE

MASTER OF EDUCATION

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The undersigned hereby certify that they have read and recommended to the Faculty of Graduate Studies for acceptance, a thesis entitled "A Multisensory Approach to the Learning of Symbols" submitted by Leverne S. Collet in partial fulfilment of the requirements for the degree of Master of Education.

ABSTRACT

The basic problem of this study was to provide a learning theory rationale which could explain why eclectic techniques of teaching reading were more successful than any single technique. It was hypothesized that, other things being equal, the efficiency of teaching techniques increased with the number of sense modalities being used. The efficiency of a technique was determined by the amount learned per unit of time.

In order to test this hypothesis, three comparable groups of junior high school students were taught equivalent tasks by three different techniques. The first teaching technique employed only visual cues, the second employed both visual and auditory cues, and the third employed visual, auditory, and kinesthetic cues. The task was to learn a set of symbols which represented certain letters of the alphabet.

A latin square design was used for the experiment in order to balance out the effects due to differences among sets of symbols and different orders of presentation. Each group of students was taught by all three techniques and used all sets of symbols. At the end of the experiment, the three groups took the same test, but the marks attained were assigned to visual, audio-visual, and audio-visual-kinesthetic categories according to the technique used for teaching the particular symbol concerned. Thus, a visual, audio-visual, and audio-visual-kinesthetic sccre was obtained for each individual. Subsequently, a second experiment was performed in order to provide replication.

The data obtained was tested for homogeneity of variance. Since no significant differences were found, an analysis of variance was performed. Some significant interactions occurred in the second experiment; therefore, a sign test was applied to the data. The results of the sign test confirmed the findings of the analysis of variance.

It was found that, in general, most students' scores increased with the number of sense modalities being used. The audio-visual-kinesthetic scores were significantly greater than the visual scores in both experiments. The audio-visual scores were significantly greater than the visual scores in Experiment Two and on the objective portion of the Experiment One test. But, there was no difference in scores on the recall portion of the Experiment One test. Audio-visual-kinesthetic scores were significantly higher than audio-visual scores in both parts of Experiment One, but the difference was not quite significant in Experiment Two.

The results of this study led to three general conclusions:

1. For most students, audio-visual-kinesthetic techniques were more efficient than visual techniques for the teaching of symbols.

2. For most students, audio-visual-kinesthetic techniques were somewhat more efficient than audio-visual techniques for the teaching of symbols.

3. For most students, audio-visual techniques were more efficient than visual techniques for teaching symbol recognition, but

there seems to be no difference for teaching students to draw the symbol from memory.

In general, the results support the contention that learning improves with an increase in the number of sense modalities involved by the teaching technique.

A C K N O W L E D G M E N T S

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CHAPTER I

INTRODUCTION

In recent times, particularly within the last century, universal literacy has become a primary goal of society. The result has been an increasing pressure on educators to develop more efficient techniques for the teaching of reading. Historically, four main teaching methods, each of which has had a period of popularity and its share of vociferous defenders, have been used. Fernald (1943) outlines these:

1. The analytic visual method is commonly called the ABC or recitation method. The child begins by memorizing the alphabet, then learns to read by laboriously connecting the spelling and pronunciation of words. For example, a child learns to read the word cat by saying, "cee-ai-tee, cat".

2. The whole-word method is often referred to as the look-and-say approach to reading because the child is taught to recognize whole sentences, and later individual words, by their overall configuration or shape. He is discouraged from analyzing the word letter by letter--at least until he has developed a sizable sight vocabulary.

3. The phonic or auditory method places great stress on the sounds of letters or letter combinations. A child is taught to read the word cat by generalizing from phonograms until he can sound out, "cuh-aa-tuh, cat".

4. The kinesthetic or tracing method depends on the development of a muscle memory. A child is taught to read cat by simultaneously tracing the word with his finger and repeating the word aloud. It is noteworthy that this method treats reading and writing as an indivisible whole.

Modern Practice

According to Gray (1956), Robinson (1946), and Fernald (1943), a great variety of experiments have been attempted by a large number of researchers, each intent on proving the superiority of particular methods. These authorities unanimously agree, however, that the research has failed to prove that any one method is better than the other. All agree that a combination of methods is desirable. As Gray comments:

> The trend all over the world has been to take an eclectic approach to the teaching of reading. This . . . . has been shown again and again in practice to be the most effective method.

He also states categorically that all specialists and most classroom teachers agree that writing should be introduced at approximately the same time as reading (i.e. within a few weeks) and should continue to be taught concomitantly.

The Need for a Learning Theory Rationale

Gray cites convincing evidence that a combination of teaching techniques produces results superior to those obtained by using any one technique singly. He does not attempt to explain why eclectic techniques

were superior. Educators generally have tended to take a pragmatic rather than a theoretical approach to method: if it worked, it was used.

The practical or technical approach described above is normal to the early developmental stages of any science, but the histories of other sciences have demonstrated that real growth in knowledge follows the development of theories which explain events and their inter-relationships. The science of pedagogy has amassed a tremendous body of descriptive information. However, further development is hampered by the lack of a unifying conceptual framework. Such a theoretical framework would suggest areas in which fruitful research could be done and thus give direction and coherence to the development of new educational practice. A learning theory rationale which explained why the concomitant use of several teaching techniques is apparently more effective than the use of any one technique might also suggest an even more efficient teaching method.

An analysis of the teaching methods reported above indicates that their relative efficacies are related to the sense modalities used in the learning process. All the teaching methods involve the visual, auditory and kinesthetic sense modalities to some extent, but the emphasis placed on each modality varies from method to method. The analytic and whole-word methods place primary emphasis on visual cues, the phonetic method stresses visual and auditory cues, while the tracing method stresses kinesthetic cues. Obviously,

a combination of methods suggests that emphasis is placed on cues from all modalities.

The problem, then, was to discover the relationship between the number of sense modalities used in a learning situation and the amount learned.

CHAPTER II

RELATED THEORY AND RESEARCH

The teaching of reading has been the subject of a great many investigations. In addition, a number of physiological and psychological studies were considered relevant to the topic. The chapter is subdivided into five main topics: (1) definition of terms, (2) educational research, (3) physiological findings, (4) psychological research, (5) learning theory.

I. DEFINITION OF TERMS

Four terms have restricted and special meanings, and shall be used throughout this study as hereinafter defined:

1. Perception: act of becoming aware of an object and attaching meaning to it in terms of previous experience.

2. Monosensory: characterized by major emphasis or dominance of one sense modality.

3. Multisensory: characterized by emphasis of more than one sense modality.

4. A multisensory approach to learning: characterized by teaching techniques which provide visual, auditory and kinesthetic cues.

II. EDUCATIONAL RESEARCH

There is some evidence that the concomitant teaching of reading and writing enables former non-readers to learn. Fernald (1943) developed a method which ensures adequate use of kinesthetic and auditory cues. The words which the child must use are written for him in large cursive letters using a material, such as crayon, which is easily distinguished by touch. Cursive letters are used in order to integrate the word into a kinesthetic unit. The child traces the word with his finger as he pronounces it, emphasizing the syllabic articulation, but <u>not</u> sounding each letter. The child now attempts to write the word without looking at the model. If he makes a mistake, he begins again, since Fernald believes that erasing or correcting destroys the pattern of kinesthetic activity elicited by tracing.

Fernald claims that all but one of the large group of non-readers which she instructed by this method learned to read. She also cited case studies of brain damaged children who learned by her method. All of this Gray (1956) called "convincing evidence" that some children, who have not learned to read by other methods, can learn by the Fernald kinesthetic approach. It is interesting to note that, while Fernald denies teaching phonics, her "marked articulation" is not really so very different from the phonogram approach to phonic instruction.

During World War Two, Allan (1958) compared methods of teaching Morse Code for the British navy. An experimental group of men were taught Morse by listening to code sent at twenty words per minute by an automatic machine while the instructor transcribed the words on the blackboard. Later, they practiced sending in patterned rhythms developed at fairly close to the machine speed, and transcribed the messages themselves. The control group was taught in the regular manner. They were given a list of letters and corresponding symbols to memorize. Subsequently they practiced sending and receiving letter by letter. Allan found that the experimental group made significantly fewer mistakes at high speeds than the control group. In terms of the amount of instruction necessary to achieve a competent operational speed, the difference was highly significant. It is of interest to note that the control group actually learned the code by visual means alone, and later transferred the knowledge to the aural modality for recognition, and to the kinesthetic modality for reproduction. The experimental group, on the other hand, used the aural and visual modalities simultaneously from the beginning, and very soon introduced the kinesthetic modality during practice.

During recent years, a number of studies have been conducted in an attempt to evaluate the usefulness of illustrations, pictures, and other audio-visual aids to teaching. According to the Dictionary of Educational Research (1960, p. 997) almost all

of these studies are poorly designed and inconclusive. A few of the more relevant and better-controlled studies, however, do provide useful background information.

Vernon (1947) compared the lecture with methods using filmstrips or movies for teaching naval mechanics. She used a large number of subjects, carefully matched the control and experimental groups, and made allowance for differences in the ability of instructors. Among other things, she found that filmstrips, when combined with notetaking, were superior to either a movie or lectures. The movie, on the other hand, was quantitatively superior to the lecture method, and, in terms of elapsed time, probably more efficient than either of the other two. In regard to the effect of kinesthetic elements, Vernon reported that filmstrips accompanied by notetaking were just as effective as filmstrips where no notes could be taken--even though the latter received a practical demonstration and the former did not. In other words, the value of notetaking in this situation was equal to the value of the practical demonstration. Since the subjects were free to study their notes, however, a large portion of the value of notetaking may be attributed to visual and memory factors.

Somewhat different results were obtained by Ash and Carleton (1953). Using four large matched groups, they showed, in two separate experiments, that subjects who took notes during a film (movie) remembered significantly less than subjects who took no

notes. The experiment was exceedingly well-controlled, and the groups were matched for reading ability, interest, and science aptitude. Ashe and Carleton concluded, logically enough, that students who took notes during a film showed lower achievement if the nature of the film was such that it demanded constant attention because the notetaking diverted attention from the film. This does not contradict Vernon's findings since a filmstrip allows time for notetaking and the movie does not.

Robinson (1946) compared surveys made by herself and others with her own detailed and complete analysis of the causes of reading failure in thirty clinical cases. She then compiled tables showing the frequencies with which sensory defects of various kinds accompanied failure. Her concluding chapter states, among other things, that 73 per cent of cases had visual problems, 45 per cent had functional hearing disorders (as opposed to only 5 per cent who were partially deaf), and 30 per cent had motor coordination problems. Since studies of the relationship between comparable intensity and the incidence of sensory disorder in <u>normal</u> readers had not been made, it was difficult to assess the extent to which sensory anomalies were the cause of reading failure. Robinson points out, however, that a child who has a functional hearing disorder probably would not learn to read by a method which relies mainly on a phonetic attack for word recognition. By implication, such a child probably would learn to read if the teaching method

includes word recognition techniques dependent on other sensory cues.

Complementary results are claimed by Ewers (1950), who correlated reading ability and auditory acuity. Analysis of auditory ability by audiometer and other machine methods provided a fairly precise measure of auditory discrimination. This was then compared with the results from a battery of reading tests. It is noteworthy that, although she found only .40 correlation between reading and auditory acuity per se, there was a .70 correlation between phonic ability and the ability to hear high-frequency sounds.

This relatively high correlation is explained by Henry (1947). In an exhaustive research program undertaken for her doctoral dissertation, she used the extensive resources of the Bell Telephone Laboratories to demonstrate conclusively that there was a link between the inability to use phonetic analysis and a partial loss of hearing in the high frequency range. She found that the sounds of individual letters in a spoken word vary in both pitch and intensity. For example, when the vowel "a" and a fricative consonant appear in the same word, the sound of the "a" was shown to be about five hundred times as loud as the consonant, while the frequency of the fricative was, on the average, about twice as high. Obviously, a child with only partial loss of hearing in the high frequency range would not be able to hear the

fricative consonant, and must depend on chance to establish the correct pronunciation. Henry followed up her findings by performing a complex, but very well designed, experiment with various kinds of reading disability cases. Among other things, an analysis of variance revealed a significantly larger proportion of people with loss of hearing in the high frequencies among retarded readers than among normal readers. It is noteworthy that this type of hearing loss can not be detected by a whisper test or a medical inspection of the ear.

Hildreth (1948) compared the concomitant improvement of listening, spoken language and written language. She reported the correlation among these variables to be higher than those found for intelligence and language. The studies to which she refers are those reported by Goodenough (1925), in which a .79 correlation between intelligence and language achievement was found. Hildreth's findings, however, are not too useful since she did not give sufficient information about her design and selection of subjects. In lieu of further information, her findings are inconclusive.

III. PHYSIOLOGY

There is little conflict among authorities with regard to the physical construction of the brain and the sense organs, although there is great disagreement about the actual operations involved. The purpose of this section is simply to clarify the physical relationships among the senses as discovered and accepted by medical science.

Douglas (1932) gives a clear and concise description of the sensory system. The senses are part of the nervous system, and, as such, composed of neurons, or nerve cells each radiating a number of root-like fibres, called dendrites, which intertwine with dendrites of other neurons. Although the dendrites do not actually touch, they are near enough to allow signals to pass from one to the other. There is neural tissue throughout the body, but some areas, called sense receptors, have a greater concentration of neurons, and a direct, and apparently special, connection with the spinal cord, and thence, the brain. According to Douglas, signals from the various sense receptors tend to converge on nerve junctions, such as the spinal cord, and compete for the pathway to the brain. The weaker stimuli are inhibited. The receptors of concern to reading and writing are the eyes, the ears, and the kinesthetic receptors. Each has its own projection area on the cortex. In recent years the cortex has been mapped by electrical stimulation, and the findings do not differ from the Douglas diagram. A dye has been found which colors the surrounding tissues without coloring the nerve fibers themselves. In this

way, it has been shown that there are direct neural connections among the sensory projection areas. In addition, each area is connected to the upper cortex, or association area, as Hebb (1949, p. 77) calls it.

Despite the fact that Douglas' book was published nearly thirty years ago, newer books differ only in detail. The most important difference is that neural action is now known to be some sort of electrical transfer. The Hixon Symposium (1951), for example, represents an attempt to evaluate the role of electric activity in the brain, and makes extensive use of an analogy with computing machines in order to explain the workings of the nervous system. Hebb (1949) also stresses the importance of the electrical nature of neural excitation, and states (p. 66) that ". . . a single impulse cannot ordinarily cross a synapse (to the next cell)--two or more must act simultaneously, and two or more afferent fibres must be active in order to excite a third." Hebb speaks of the sensory signals converging on the cortex, and argues that each additional signal adds to the total reaction and to the strength of the memory trace formed. Another important point made by Hebb is that there is continual electrical activity in the cortex. In effect, this suggests that incoming impulses are superimposed on an already-existent circuit by which they may be modified.

A minor difference between Douglas and more modern writers concerns the differentiation of the sense modalities. Bartley (1958) presents evidence to suggest that there are really ten sense modalities. However, the only effect of concern to this paper is that the kinesthetic sense is sharply distinguished from the tactual sense.

A series of experiments by Sperry (1951) serve to illustrate some kind of intersensory neural connections. Since the experiments were done with frogs, the findings are not directly applicable to human perception, but might explain some perceptual anomalies. In Sperry's experiment, frogs eyes were rotated, by surgical operation, through one hundred eighty degrees. The frogs now perceived up as down, and vice versa, a phenomenon apparent in their attempts to catch a fly. In a later experiment, the optic nerves to the eyes were cut, and connected to the opposite eyes. The frogs now perceived a fly on their right, but struck left. When the operations were performed on embryo salamanders, the grown salamander exhibited the same sort of behavior, indicating that visual orientation is not learned, and that there is a direct connection wired in, as it were, from the visual receptors to the motor portions of the brain.

IV. PSYCHOLOGICAL RESEARCH

It was suggested by Douglas in the previous section that the fact that all signals to the brain converged on substantially the same nerve centers implied that satiation of one sense modality would inhibit signals from the other senses. A number of psychologists have conducted experiments designed to test this theory.

Ingram (1956) varied the brightness of visual stimulations and measured the auditory threshold at each level of light intensity. The auditory stimuli were presented at random strengths, from a constant distance, and close control was exercised over extraneous noises by

using a soundproofed room. Precise physical measures of the intensity of both sound and light were obtained. Since there was considerable replication, his report of a significant rise in auditory threshold during intense visual stimulation constituted strong evidence that there was some intersensory inhibition.

Broadbent (1952) carried out a somewhat similar experiment in which he compared the performance of groups in tasks which called for the ability to follow verbal instructions involving some motor responses with and without auditory distraction. He found that the distracted group made significantly more mistakes than those without distractions. A large number of subjects were used, the control and experimental groups were matched, and the experiment was replicated. The indications are that a significant amount of inhibition did take place. However, the interference could have occurred within the auditory modality itself, and is therefore not definitive evidence of intersensory inhibition.

Still other experimenters have attempted to show that stimulation of one sense modality will facilitate reception by other senses. Forest (1957) showed a number of nonsense syllables to fifteen undergraduates for three seconds to familiarize them with the spelling. The subjects then listened to tape-recorded repetitions of the list involved. He subsequently measured their visual threshold of recog nition by counting the number of tachistoscopic exposures, at one tenth second each, necessary for correct recognition of each word. The number of exposures necessary for recognition decreased with the

amount of auditory practice. However, it appeared that the amount of auditory practice increased with each subsequent list, and consequently the observed improvement could have been attributed both to the subjects' increasing adaptation to the tachistoscopic procedure and to improved visual discrimination through practice. In any case, the experiment was contaminated by a visual presentation which preceded the auditory practice. Finally, since his subjects were university women and probably both more verbally oriented and more intelligent than the general population, his findings are of limited value.

A similar, but somewhat more complex, experiment was conducted by Postman and Rosenweig (1956). They used nonsense words to test the transfer between the auditory and visual modalities. The lists were carefully equated in terms of frequency of occurrence of the syllables comprising the nonsense words in normal English. One hundred fifty subjects were divided into six groups at random. One group received auditory training and an auditory test, a second group received auditory training and a visual test, a third group received visual training and an auditory test, and a fourth group received visual training and a visual test. The remaining two groups acted as controls, receiving no training at all. The groups tested in the same modality as they were trained in were better than the controls ($p = .01$); the visual training, auditory test group were better than the controls ($p = .05$); while the group which received auditory training and a visual test fell just short of a significant difference.

Other experimenters have investigated the effect of prior stimulation of one sense modality on the sensitivity of other modalities to stimulation. In experiments that were carefully controlled and amenable to the use of fairly precise measurements, Child and Wendt (1938) found that visual stimulation, in the form of light, which preceded a sound lowered the auditory threshold a significant amount. Kravkov (1934) used similar means to demonstrate facilitation in visual acuity after auditory stimulation.

Two investigators, Jaffe and Gaydos, have experimented with the transfer of practice between the visual and kinesthetic modalities. Jaffe (1956) used twenty laboratory personnel as subjects, and randomly assigned them to two equal groups. Members of both groups wore opaque goggles, and were asked to "measure" objects with a rule, by touch alone. Jaffe had hypothesized that he would find a decrease in accuracy if he induced visual satiation. He then projected pictures of the object being measured into the goggles worn by one group. He found that when the images were representative of the size of the object being measured, the subjects produced more accurate measurements than the control group, and further, that when he varied the size of the image, the measure varied in the same direction. Jaffe concluded that there was no inhibition in his experiment, and that there was, in fact, facilitation. He subsequently repeated the experiment with substantially the same results.

Gaydos (1956) used forty men and forty-six women undergraduates, which he divided into two groups carefully equated for age, sex, and

education, to study the transfer of discrimination of form from the tactual-kinesthetic modality to the visual modality and vice versa. One group was given visual training and a tactual test, the other tactual training and a visual test. The material to be learned was names, such as Sam, Bill or Jim, for each of a number of shapes cut from masonite; the subject had to identify the masonite form by name when it was presented to him. The test of transfer was the ability to recognize the masonite forms in the untrained modality. The correlations of the tests were high in either order (.81 and .90 respectively) and facilitation, in terms of time saved in re-attaining a perfect score, was significant ($p = .05$). It is regrettable that Gaydos gave no information about the order of presentation. If the forms were not equally difficult to recognize, the sequence of presentation would have to be held constant in order to maintain group to group comparability. Since the absolute growth within each group would not be affected, however, the experiment does offer evidence that intersensory transfer does occur.

Talland (1959) experimented with the effect of visual set on aural identification of words. In order to interpret the results, it is necessary to review briefly the effect of set within a single sense modality. In a previous study (1958) Talland had discovered that clear enunciation of the class name, e.g. birds, would consistently and significantly improve the subjects' ability to recognize the names of birds which had been taped and played back at a uniform volume. The words were carefully matched before presentation, and

a good deal of replication was provided. A counter set procedure allowed him to measure the opposite effect, which was significantly negative. The procedure in the test of intersensory transfer was the same, except that the set was given visually, on a screen. The visual set facilitated auditory discrimination at the $p = .01$ level of confidence--the same significance that had been obtained from an auditory set. There was little information in either study regarding the selection or assignation of the subjects, but the design seemed adequate. The findings were therefore considered valid.

Finally, we may return to Ryan's (1940) findings. After a comprehensive review of the research, he concludes that there is ample evidence of some intersensory transfer. In particular he observes that related concomitant perceptions, as, for example, when an animal is perceived as the source of a noise, will cause transfer to occur.

Summary

There is considerable evidence that both intersensory facilitation and intersensory inhibition occur. These two effects, however, are neither contradictory nor mutually exclusive. Stimulation of a sense modality apparently inhibits simultaneous reception in the other modalities, but facilitates later reception in the other sense modalities. However, when two senses are activated by stimuli perceived as emanating from the same source there is, apparently, mutual facilitation of perception in spite of the fact that the stimulations may occur simultaneously.

There is also considerable evidence that training in one sense modality facilitates learning in the other modalities.

V. THEORY

The question which arises naturally from the review just presented concerns some theory of learning within which the observations may be placed. Such a theory must explain, among other things, why a combination of the look and say and phonic teaching methods should be superior to the exclusive use of one method, and why the addition of kinesthetic practice should enable some former non-readers to learn to read. It must account for intersensory facilitation and inhibition, and the interrelationships of perception, motor response, and previous learning.

Perhaps the most influential figures in the area of behavioral theory are Thorndike, Watson, Guthrie, Skinner, Kohler and Koffka, and Osgood. They are certainly representative of the major approaches to learning, namely, associationism, behaviorism, Gestalt psychology, and neo-behaviorism.

Thorndike

Thorndike (1913) suggests that trial and error learning is characteristic of both man and lower-order animals. A comparison of the learning curves of humans and animals led him to believe that the majority of school learning is fundamentally the action of the laws of effect, exercise, and readiness (p. 23). In the following account,

Thorndike's general laws and principles are stated so as to apply particularly to school learning.

Law of Effect. According to Thorndike, learning consists of a series of stimulus-response connections. The strength of a connection, he contends, is a function of the consequences of the response. Each stimulus can elicit a number of different responses. The learner, at the first presentation of a stimulus, makes a random selection from his repertoire of equi-probable responses. If the consequences of a particular response are satisfying to the learner, the probability of the response recurring at the next presentation of the stimulus is increased, but if the consequences are dissatisfying, the probability of its recurrence is decreased. The greater the satisfaction or dissatisfaction, the greater the strengthening or weakening of the connection between stimulus and response.

Law of Exercise. The law of exercise states that the strength of a connection is a function of the number of pairings of stimulus and response. A great deal of practice results in overlearning, disuse results in forgetting.

Law of Readiness. The law of readiness refers to the preparation of neurons for later activity. Chaplin and Krawiec (1961, p. 187) interpret the law of readiness as preparatory set. If a learner is set for an activity, it is satisfying; if the learner is forced to do something he does not want to do, the experience is annoying.

In addition to the three laws outlined above, Thorndike (1913, pp. 22-30) lists the following principles:

(1) Multiple response. Students are capable of varying their responses, and may try several before stumbling upon the one which is successful.

(2) Set. Whether a student will receive satisfaction or annoyance from the consequences of a response is determined in part by his level of aspiration.

(3) Prepotency of elements. A student can distinguish between the important and unimportant elements of a problem.

(4) Response by analogy. Students confronted with new situations may perceive it as being similar to one encountered previously. They then respond as they did on the previous occasion. According to this principle, transfer of training occurs if two situations have identical elements.

(5) Associative shifting. A response learned to one stimulus may be shifted to another stimulus. This may be done by first adding the new stimulus, and then, after it is firmly associated with the response, removing the original stimulus.

To be useful in this study, a theory must explain the apparent superiority of eclectic techniques for the teaching of reading. The basic elements in reading, according to Thorndike, are words. Reading is learned by forming evocative relationships between words and their printed symbols. Since the consequences of a response to a printed symbol are independent of the teaching technique, the law of effect applies equally to all methods.

According to the law of exercise, the more frequently a symbol is paired with the appropriate response, the more students will learn. The look and say method permits more pairings per hour than the analytical ABC and phonic methods, and they, in turn, permit more pairings than the kinesthetic method. However, the law of exercise does not explain why some formerly retarded students can learn by the kinesthetic method. Nor does it suggest a reason for the superiority of combined methods. In addition, Hilgard (1956, p. 25) states that Thorndike, in September 1929, announced to the International Congress of Psychology in New Haven that he had been wrong about the effects of punishment and the law of exercise. Thorndike repealed the law of exercise because of his own experiments. In these experiments subjects asked to draw a line three inches while blindfolded did not improve with practice.

The law of readiness is primarily a statement of the necessity of good motivation. It does not provide a means of determining what will produce the greatest motivation, and is therefore of no value in comparing teaching methods.

Since none of Thorndike's three laws could explain the superiority of eclectic techniques for the teaching of reading, it was decided that his theory was inadequate for this study.

Watson

In his first book on behaviorism, Watson (1914, p. 9) states that psychology should properly be concerned with objective description

of behavioral acts in terms of stimulus and response, habit formation, habit integration, and the like. Behaviorism should aim at predicting the response from a given stimulus, and predicting the antecedent stimulus from a given response. He attempted to build his learning theory within this frame of reference.

Watson argues (1914, p. 212) that the execution of one movement became the kinesthetic stimulus of the next movement. As evidence of the cruciality of the kinesthetic sense, he pointed out that, in his experiments, the maze learning ability of animals which had been blinded and deafened was not significantly different from that of normal animals. Watson states that animal learning can be explained by the laws of frequency and recency. The law of frequency is similar to Thorndike's law of exercise. Animals tend to repeat the responses they have made most frequently in the past. The law of recency states that the latest response will be favored in recall. Watson repudiates the law of effect because he felt that Thorndike's ideas of satisfaction and dissatisfaction were too subjective.

Watson's theory was of particular interest in this study because of his emphasis on kinesthesis. However, he failed to prove that kinesthesis was the crucial sense. Chaplin and Krawiec (1960, p. 201) state that animals which are blind, deaf or anosmic can learn a maze, but that animals deprived of all three senses show no significant learning. In addition, Watson's entire frequency-recency theory is subject to the same criticisms which led Thorndike to de-emphasize the law of exercise. Consequently, Watson's theory was not considered adequate for this study.

Guthrie

To Thorndike, there were two kinds of learning: selecting or connecting, and associative shifting. The latter originated as a subsidiary law and was not considered very important. Guthrie made the associative learning the cornerstone of his system: trial and error learning of the selecting and connecting sort was considered to be derivative, and of minor importance. Like Watson, he concentrated on observable movements.

Guthrie (1935) believes that an association gains its full strength with the first pairing of a stimulus and response. He postulates that improvement refers to the outcomes of learnings and that it consists of a complex combination of movements, each of which can form a connection with a cue. Learning improves with practice because the number of discrete connections increases, and not because of any qualitative change in the connection. He does not believe in the decay of cue response, but attributes the fact of forgetting to interference through the learning of an incompatible response. Guthrie stated his one law of learning as: "A combination of stimuli which has been accompanied by a movement will on its recurrence tend to be followed by that movement" (p. 26). The simplicity of Guthrie's theory may, however, be the cause of some criticisms such as those of Seward (1942), who found that rats learned to push a bar faster when rewarded with food than when unrewarded. Seward states that in respect to the effect of reinforcement, Guthrie's theory appears inadequate.

In a comprehensive critique, Osgood (1953, p. 370) suggests that Guthrie's theory is untestable. Guthrie said that if a stimulus situation has been associated with a response, it will, on recurrence, elicit the same response. Empirical evidence showed that there were exceptions: Guthrie's apologists countered with the irrefutable statement that there had been unobservable changes in the stimulus situation. Guthrie's theory is difficult to prove or disprove, according to Osgood, because it can be used to predict either of two plausible outcomes to an experiment. The theory can not be used for prediction, therefore, until much more precise measurements of stimulus situations, including internal ones, are developed (p. 372). At the date of this writing, no such measuring methods were available.

Skinner

The theory of operant conditioning which B. F. Skinner (1938) proposes is similar to Thorndike's selecting and connecting. Like Thorndike, Skinner recognizes two kinds of learning, and like him he places more emphasis on learning which is controlled by its consequences. Learning, to Skinner, consists of two kinds of conditioning which he calls type S and type R.

Type S conditioning makes use of "built-in" respondent behavior to an unconditioned stimulus, such as the constriction of a pupil in strong light. A second stimulus S_2 can, after being presented with the unconditioned stimulus, come to elicit the response. Type S conditioning is comparable to Thorndike's associative shifting. Skinner

suggests (1938, p. 112) that this type of conditioning is limited to autonomic responses.

Type R or operant conditioning, Skinner (1938, p. 45) considers much more important than type S. An operant is defined as an emitted response which is not elicited by a known stimulus. In type R conditioning, the response becomes correlated with a reinforcing agent. For example, if a rat accidentally presses a lever which causes food to be ejected into his cell, the response may be strengthened: Skinner argues that the movement of pushing the lever (a response) is important--the lever itself (a stimulus) is not. Reinforcement is contingent upon the appearance of a response. Skinner's law of acquisition for Type R conditioning states: "If the occurrence of an operant is followed by presentation of a reinforcing stimulus, the strength is increased." (1938, p. 21).

Type R conditioning appears very similar to Thorndike's law of effect. However, Skinner is simply describing what happens, while Thorndike seeks to explain responses in terms of satisfaction and dissatisfaction.

The law of acquisition is supported by Skinner's experiments in conditioning rats to push a bar. A hungry animal is placed in a Skinner box and allowed to explore it. Whenever the rat happens to press the bar, a pellet of food is dropped. After the first few spontaneous responses, conditioning proceeds rapidly. The progress of the conditioning is measured by the number of responses per unit

of time, usually per hour. The total number of responses can then be plotted against time to form a learning graph.

In a subsequent book, Skinner (1953) discusses the concept of a generalized reinforcer, that is a condition which has been associated with primary reinforcers to the extent that it becomes a reinforcer itself. He suggests that money is a prime example of a generalized reinforcer (p. 79). The generalized secondary reinforcers may be either positive or negative depending on whether the primary reinforcer was reward or punishment.

Skinner (1953, pp. 93, 94) explains induction, or transfer of training, by stating that stimuli and operants are not discrete units but, rather, classes of events. Transfer occurs because of identical elements within the classes.

Skinner (1954) suggests that a machine should be more efficient than a human in the teaching of reading. The machine, he states, has the advantage that a precise schedule for reinforcement, order of presentation, and systematic review can be "built-in". Whether or not Skinner's claims are justified is not of direct concern to this study, since machines may be devised to employ any teaching technique.

Skinner (1953, pp. 210-216) suggests that verbal learning is a highly complex form of operant conditioning. Chance sound groupings form words which are subsequently reinforced by the hearer. While it seems possible that many words may be learned in this fashion, operant conditioning does not explain the effect of a conscious attempt to imitate words. Common experience indicates that a large percentage

of a child's vocabulary is acquired through conscious imitation. New words are very often learned at the first attempt. Such one-trial learning can not be termed conditioning in the usual sense. In addition, the validity of Skinner's experimental findings has been questioned by Finan (1940). Studies from Hull's laboratory, Finan states, found that "rate of response (was) an extremely variable measure of conditioned behavior and tend to indicate that the total number of responses or total time consumed during the response is a more precise index of behavior." Finan recommends great caution in generalizing from Skinner's experiments because of their doubtful validity. It seems particularly appropriate to be cautious when generalizing to verbal learning.

It was stated previously that an adequate theory should explain the apparent superiority of eclectic techniques of teaching reading. According to the theory of operant conditioning, all teaching techniques would be equally effective if they offered identical patterns of reinforcement. It could be argued that the look and say technique permits a greater rate of response than the analytic or tracing techniques, and consequently would permit more reinforcements to be made. According to this line of reasoning, the look and say method would be superior to the others either individually or in combination. Since this conclusion contradicts the observed facts, Skinner's theory was considered inadequate for this study.

Kohler and Koffka

Kohler (1927) describes a series of experiments designed to show the importance of insight in learning. He describes a large number of experiments, but two will serve as illustrations. Kohler (p. 14) brought a fifteen month old girl into a "blind alley" so designed that she could see an attractive object through a window in the partition, but must turn from the window and detour through a door in order to reach the goal. Kohler reports that the little girl, after pressing against the window for a short time, saw the door, laughed joyfully and went immediately to her objective. This sort of behavior, he contends, is typical of insight learning.

Perhaps the most widely known of Kohler's experiments involved the use of sticks as implements. According to Kohler's description (p. 127) bananas were placed a short distance from an ape's cage. The animal was then given two bamboo sticks which when fitted together were long enough to reach the bananas. The ape tried to reach the fruit with first one stick and then the other, but was unsuccessful. Then, apparently defeated, he squatted on a box and played carelessly with the sticks. While playing, he accidentally pushed one stick into the other. Immediately, the ape ran to the railings and began to draw the bananas towards him.

Koffka (1935) uses the results of Kohler's experiments to build a Gestalt theory of learning. However, his book is very large, and too loosely organized to permit an adequate treatment in a limited space. In fact, Hilgard (1956, p. 226) accuses Koffka of applying the laws of

organization to learning problems in a manner "too casual to be very convincing". Hilgard goes on to outline a learning theory based on Koffka's ideas. According to Hilgard (pp. 226-8) Koffka's learning theory consists of the law of Pragnanz and the subordinate laws of similarity, proximity, closure, and good continuation.

The law of Pragnanz is similar to the laws of equilibrium in physics. The organization of a perception always tend to move towards the good gestalt, that is, isomorphic representations of the physical world. A good gestalt is regular, simple (or uniform), and stable. Learning situations induce disequilibrium. By implication, the law of Pragnanz results in a new perception in order to attain equilibrium. Thus, Kohler's apes were presented with perceptual problems and literally "saw" the solution.

The four subordinate laws are special applications of the more general law of Pragnanz. The law of similarity states that items alike in form or color tend to form perceptual groups. According to the law of proximity, perceptual groupings are favored according to the nearness of parts. In learning, proximity in time is favored: as in the law of recency, old impressions are not recognized as quickly as new ones. The law of closure, as applied to learning, refers to the importance of goal attainment. Used in this way, closure is an alternative statement of Thorndike's law of effect. A problem situation is seen as an incomplete whole which creates tension (dissatisfaction). Attainment of the gcal achieves closure (satisfaction). The law of good continuation implies a sort of perceptual inertia

such that straight lines appear to continue as straight lines, partial circles tend to become circles, and so on. In learning, cues and responses which form a regular pair are easier to learn than those fitting less well.

The fact that learning is interpreted as organization places a great deal of emphasis on the whole. In fact, Boring (1930) states that "the stress is shifted from the law of contiguity to the law of organization. Reproduction is by wholes, within wholes, or for wholes". Gestalt psychology, then, would predict that the whole word or look and say method of teaching reading should be superior to analytic or combination methods. This prediction is contrary to the facts. Consequently, the Gestalt psychology of Kohler and Koffka was considered an inadequate theoretical basis for this study.

Osgood

Osgood (1957a, p. 75) suggests that no single stage theory can adequately explain all types of learning. He states that both SS and SR theories are incomplete. Gestalt psychology (SS) describes relationships among input events, but says little about how they eventuate in behavior. The SR theories, on the other hand, deal adequately with simple stimulus-response relations, but say little about the integration of sensory events (perception), or the integration of response events (motor skills).

The theory which Osgood (1957a, p. 76) proposes consists of two stages: decoding and encoding. Decoding refers to the "total process

whereby physical energies in the environment are interpreted by an organism". Encoding refers to the "total process whereby intentions of an organism are expressed, i.e. turned into environmental events".

Osgood (1957a, p. 76) states that his theory shall "necessarily imply a conception of how the nervous system operates". In another paper, Osgood (1957b) speaks of four neurophysiological levels within each behavioral stage:

The first level consists of the afferential nervous system, or sense receptors, in the decoding stage, and the efferential nervous system, which directs muscular activity, in the encoding stage.

Second is the projection level. At both the sensory and motor ends, the projection level is "essentially a neural relay system between the peripheral apparatus of the organism and the central nervous system". Osgood (1957a, p. 78) states that the projection level is characterized by isomorphism and the inability to modify through experience. The receptor surfaces are rather precisely mapped on the sensory cortex.

Third is the integration level. Osgood (1957b) speaks of sensory integration as being "driven" from the projection system so that "the redundancies of the environment come to be mirrored in (the nervous structure of) the cortex". In the decoding stage, integrations of motor responses occur. Osgood quotes experimental results which suggest that rapid motor sequences, such as piano playing, do not allow time for proprioceptive feedback. This, he states, is evidence that motor integrations take place.

Repeated pairings of stimulus or response events result in "an increased dependence of one upon the other" (1957a, p. 79). With repeated psirings, a predictive relationship between events is formed such that the firing of the nervous correlates of one results in a "tuning up" of the correlates of the other. With extremely frequent pairings of events, an evocative relationship is formed such that the firing of the nervous correlates of one is sufficient to fire the correlates of the other. These two relationships account for conditioned behavior.

Fourth is the representational level, which may act as a mediator between stimulus and response. Osgood (1957a, p. 92) states that certain stimuli are significates, that is, they have a "wired in" association (reflex action). If a non-significate stimulus is regularly accompanied by a significate, it will acquire an association with part of the behavior pattern elicited by the significate. This fractional behavior is known as a representational mediational process. It may become anticipatory and produce self-stimulation. Osgood states that the generalization between words such as "joy" and "glee" is evidence that a mediating reaction has occurred. "Joy" and "boy", which are more similar physically (contain more identical elements), do not share a generalized meaning.

Osgood (1957a, p. 106) gives the diagrammatic interpretation of the acquisition of language reproduced in Figure 1. He believes that syllables are the basic functional unit. They form an "evocative relationship on an all or none basis". For example, one could hear

"tractor" or "tracker", but not both words. These unit autonomisms require little integration, and may occur at the projection level.

Syllabic associations are formed by the frequency with which certain sequences occur in common words. These "sequential autonomisms" are predictive rather than evocative relationships: integration is required, but little or no mediation. Grammatical sequences form predictive associations in a similar manner.

There are a number of principles upon which the learning model operates. Three of these are of particular significance to the teaching of reading. The wording used here follows Osgood (1957b).

(1) The strength of integrations depends not only upon the number of pairings which occur, but also upon the temporal contiguity of those pairings.

(2) The strength of associations and integrations among stimuli and responses depends upon their spatial propinquity. Spatial propinquity refers to the amount of nervous tissue available to a particular association or integration, and to the density of nervous fiber within the tissue.

(3) A single stimulus produces a divergent hierarchy of responses. The addition of sensory cues associated with the same stimulus event forms a convergence of stimuli which reduces the divergence among the responses.

The superiority of eclectic techniques for the teaching of reading is explained by Osgood's third principle. The look and say method teaches children to recognize words by such sensory cues as the overall

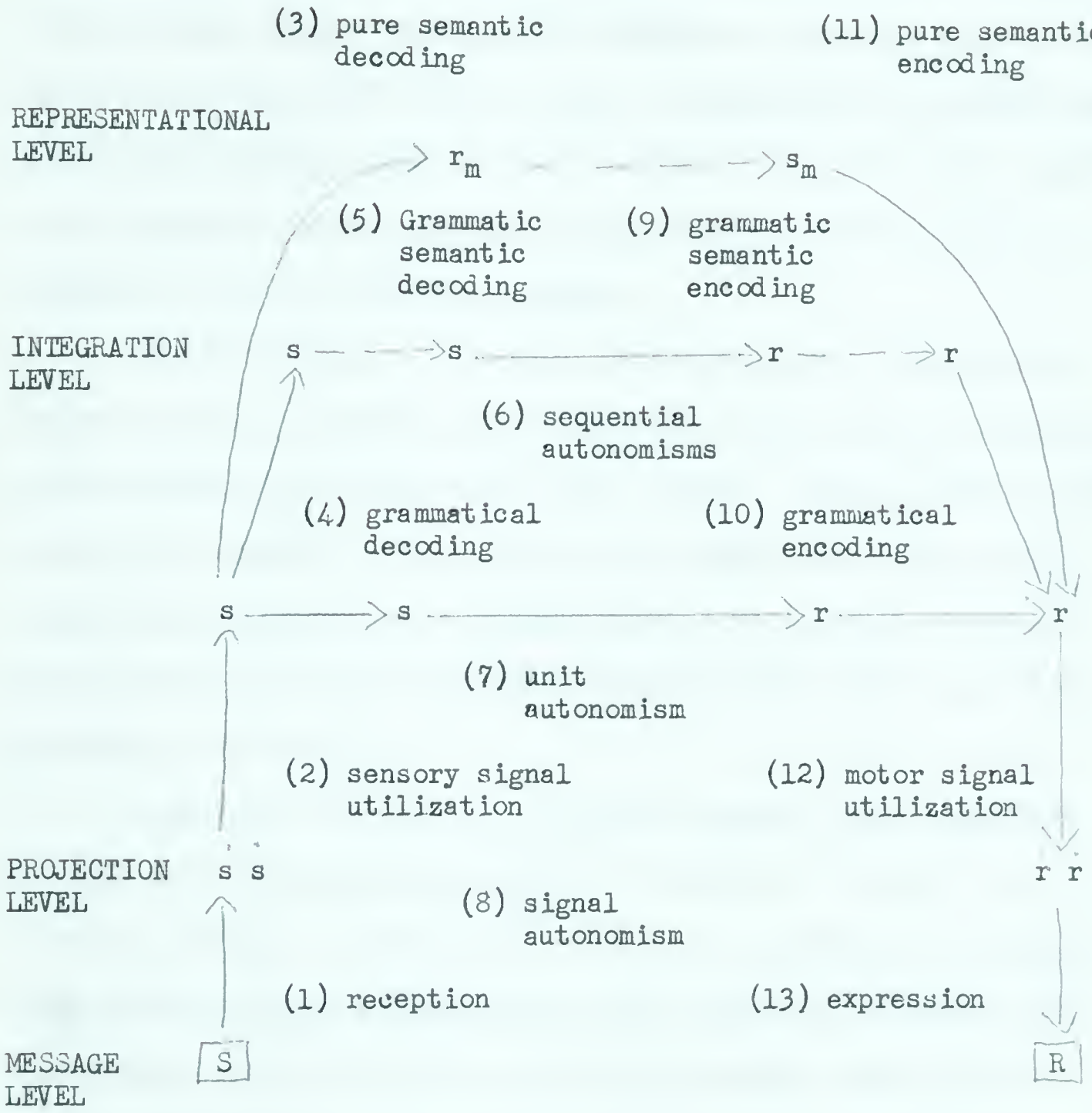

Figure 1. Osgood's Model of Linguistic Decoding and Encoding

shape of the word; the ABC method depends upon a memorization of letters and letter sequences; and the phonetic method depends upon associating certain letter groupings or phonograms with their sound. Each method uses a particular type of cue. A combination of methods, then, would have a larger number of cues associated with each word. According to Osgood's third principle, then, eclectic methods would be superior to any one individual method.

If the addition of phonetic techniques to the look and say method resuts in improved word recognition, there must be interfacilitation between the auditory and visual senses. Osgood (1957a, p. 109) states that feedback from one sense may operate selectively among alternative integrations in another sense. For example, a Gilbert and Sullivan chorus may seem quite unintelligible unless a printed libretto is available.

Among those reviewed, only Osgood's theory could adequately account for the apparent superiority of combined techniques for teaching reading. In addition, the theory is systematic and consistent without having an inordinately large number of principles and postulates. It is, therefore, the best conceptual framework for this investigation.

CHAPTER III

THE PROBLEM

The basic problem was to provide a testable learning theory rationale which could explain why certain techniques for teaching reading were more successful than others. Osgood's second principle states that the strength of an integration or learning was directly dependent upon the amount of nervous tissue available. Physiological evidence quoted previously suggests that each sense modality has a separate projection area on the cortex. An integration which has cues from two sense modalities will therefore have more nervous tissue available to it than one which depends on cues from one modality. It therefore follows that, other things being equal, the strength of an integration increases with the number of sense modalities being used. This relationship shall be called <u>the principle of multisensory learning</u>.

The principle of multisensory learning is supported by the findings of the psychological studies reviewed in Chapter Two. Trans-sensory set and trans-sensory learning were illustrated. Intersensory inhibition was produced when two or more senses received unrelated cues simultaneously; but, intersensory facilitation resulted when cues from various sense modalities were perceived as emanating from the same source. The strong association which Henry (1947) found between reading retardation and relatively small losses of hearing illustrates the importance of auditory cues in reading.

Evidence was cited in the previous chapter that eclectic techniques were superior to any one technique for the teaching of reading. The principle of multisensory learning offers an explanation. The look and say method emphasizes visual cues, the phonetic method emphasizes auditory cues, and the Fernald method emphasizes kinesthetic cues. The eclectic method places emphasis on all three sense modalities: therefore, more nervous tissue is available and learning is facilitated.

The principle of multisensory learning is central to an Osgoodian rationale for the teaching of reading because it was deduced from Osgood's principle of spatial contiguity and the related physiological knowledge regarding the structure of the central nervous system. Therefore, it was decided to investigate the relative efficacy of multisensory and monosensory techniques for the teaching of symbols. The results of this investigation could be valid only if the effects of varying the number of sense modalities could be isolated. The effect of variance in the number of pairings was most difficult to control: it was manifestly unfair to equate one visual presentation of a symbol with one kinesthetic presentation, since writing a symbol took as much time as several visual scannings. It was therefore necessary to assume that the only practical criterion of efficacy was time: the technique which produced the most learning in a given length of time was the most efficacious.

THE HYPOTHESES

The general hypothesis was that the amount of learning increased as the number of sense modalities involved by a teaching technique increased. The study was limited to the three modalities emphasized in the teaching of reading: visual, auditory and kinesthetic.

Specifically, it was hypothesized that if, in a given time, students were taught three equivalent tasks, one by visual techniques, one by audio-visual techniques, and one by audio-visual-kinesthetic techniques, the following relationships would prevail:

(1) Subjects would obtain significantly higher scores in tasks taught by audio-visual techniques than in tasks taught by visual techniques.

(2) Subjects would obtain significantly higher scores in tasks taught by audio-visual-kinesthetic techniques than in tasks taught by audio-visual techniques.

(3) Subjects would obtain significantly higher scores in tasks taught by audio-visual-kinesthetic techniques than in tasks taught by visual techniques.

In addition to the three specific hypotheses enumerated above, a secondary hypothesis was suggested by the nature of school experiences. For most students, the majority of school time has been spent in some reading activity. Since reading involved verbalization, even silent reading probably involved a certain amount of auditory stimulation. Kinesthetic practice, however, could not be internalized to

the same extent. It was therefore hypothesized that the addition of the kinesthetic modality would result in a greater increase in learning than the addition of the auditory modality.

CHAPTER IV

THE PROCEDURE

I. SUBJECTS

The subjects for the experiment were chosen on the basis of availability and suitability. The students of Wilson Junior High School in Lethbridge, Alberta, were easily available. In addition, junior high school students were intrinsically better suited to an experiment such as this than pre-school children for two reasons. First, cumulative records, which could be used as a basis for comparing groups, were available for the older students. Second, the learning task to be used required that either all the students should be familiar with the alphabet or else all should be unfamiliar with it. Since even very young children have had some experience with letters and words, unfamiliarity was judged impractical. It was therefore decided to use subjects familiar with the alphabet. Since elementary school children were not easily available, four classes of grade eight students from Wilson Junior High School were chosen as subjects. Three classes--Room 201, Room 203, and Room 204--were chosen to participate in the experiment, while the fourth class--Room 202--was used for a pilot study.

The rooms in Wilson Junior High School were heterogeneous by design, that is, an attempt had been made to place the same number of low, average, and high ability students in each room. Rooms 201,

202, and 203 had twenty-eight, twenty-nine, and twenty-nine students respectively. In order to balance the design, twenty-five students were used from each room. The experimental subjects were chosen on the basis of their scores on the Henman-Nelson Intelligence Test Form A for grades six to nine. Although it was not possible to match the groups on a one to one basis, fairly close comparability was attained. The intelligence scores for each subject are reported in Appendix A, and summarized in Figure 1. Bartlett's test for homogeneity of variance produced an F ratio just above unity, and the t test ($p = .20$) applied to the maximum difference among means fell well below significance. It was therefore concluded that the three groups of subjects were of comparable abilities.

Subjects	Room 201	Room 203	Room 204
Mean I.Q.	111.56	111.16	111.32
Standard Deviation	13.61	13.37	13.41
F max = 1.04		Maximum t = .04	
F max (.95) = 2.04		$t_{.20}$ = 1.300	

Figure 2. Summary of I.Q. Scores

II. THE TASK

Four criteria governed the selection of task materials: (1) simplicity, (2) familiarity, (3) objectivity, and (4) similarity to reading. The most obvious choice, actually learning to read, was discarded because of the length of time involved and the almost impossible task of controlling the teaching techniques used. Also consideration for the individuals involved demanded that our best efforts be used in teaching each child a skill so vital as reading: for this reason it was decided to use a task similar to reading but not vital to the future development of individual pupils. Words or nonsense words were judged so difficult to equate for past experiences pupils may have had as to make a valid study prohibitive. A set of symbols representing our alphabet and specifically designed to require the same sorts of visual discriminations as the letters of the alphabet, presented a learning task similar to the discriminations one must make in learning to read and, in addition, had the advantage of being unfamiliar to the subjects. The task was therefore set as learning the confusabet symbols for the upper case letters of the alphabet (see Figure 3, p. 48). It is noteworthy that the task is not directly comparable to reading words since recognition of single symbols rather than a sequence of symbols was involved.

In order to provide replication of experimental results, the twenty-six symbols were divided into two groups to be used in two separate experiments. For each experiment, a partially balanced

design was struck; in each experiment, three comparable sets of symbols were used with the three rooms of students. Six groups of four symbols each and one group of two symbols were developed; the two-symbol group was used for sample questions.

The letters and their corresponding symbol were then drawn on four by six filing cards, the letter on the left in red and the symbol on the right in black (see Figure 3). A fold was made down the center of each card so that either the letter or its symbol could be presented individually. Each was then presented, in turn, to the author's four school-age children, and the similarities and difference from letter to symbol were cooperatively analyzed. The cards were subsequently presented in the folded position so that only the symbol was visible, and the children asked to identify the letter it represented. The cards were divided into four piles as follows: (1) eight cards which were identified after only one or two presentations, (2) eleven cards based on the numeral 8, (3) four cards in which only the symbol orientation varied, and (4) the three remaining cards. These four piles were then used to divide the cards into the seven sets shown in Figure 3. In order to make the groups of cards equally difficult as learning tasks, the seven groups were formed as follows:

(1) Two cards were chosen from the first pile to form the sample set. The remaining cards in this pile were distributed one to each set at random.

(2) Three cards were chosen at random from pile three and distributed to sets 4, 5 and 6.

(3) Sets 4, 5 and 6 were then completed with six cards from pile two. Each set thus contained two symbols based on figure 8.

(4) The three cards in pile four were distributed at random to sets 1, 2, and 3.

(5) The five cards remaining in pile two were distributed at random. Set 1 received one card and sets 2 and 3 two cards each.

(6) The remaining card in pile three was put in set 1.

(7) The cards were arranged in what appeared to be an ascending order of difficulty from left to right. Each card was then labelled according to the set to which it belonged and its position within the set.

The last three sets, collectively, appeared to be more difficult than the first three. However, since the first three sets were used in Experiment One and the last three in Experiment Two, the card sets used within each experiment should be closely comparable. The more difficult cards were purposely left for the second experiment, since some facility in handling this sort of material should be developed by the subjects during the first experiment.

III. TASK ENVIRONMENT

A regular classroom of Wilson Junior High School was chosen as an adequate site for the experiment. The teacher's desk was placed at the front and center position to ensure that each student could see the cards clearly. This procedure occupied the first minute or two of each experimental period. During the pilot study, it was

SET 1 Cards

SET 2 Cards

SET 3 Cards

SET 4 Cards

SET 5 Cards

SET 6 Cards

SAMPLE Cards

Figure 3. Letters and corresponding symbol (developed by Mildred C. Letton)

discovered advisable to place an eighteen inch screen on the front of the teacher's desk so that all manipulations of the cards were hidden from the subjects' view.

IV. THE PILOT STUDIES

Once the logical forms for the teaching techniques were developed, a pilot study was used to find practical time limits for each of the card presentations. The twenty-nine students of Room 202 were the subjects used to get this information. Set 1 cards were presented by the V techniques; Set 2 cards were presented by the AV techniques; and Set 3 cards were presented by the AVK technique. From the pilot study, the following information was gathered:

(1) A screen was necessary to keep subjects from using the position of a card as a mnemonic aid, and to keep subjects from seeing the answer side of a folded card.

(2) The original two and one half minutes scheduled for each step was found to be too long, and was subsequently cut to two minutes.

(3) A routine was developed which greatly facilitated the manipulation of the cards.

(4) The use of verbal cues and a stop watch were found effective in maintaining a steady pace.

(5) The subjects could go through three groups of cards taught by three different techniques and then write a seven minute test within one thirty seven minute period.

(6) Five minutes was ample time for the objective (or recognition) test. The recall test was timed for two minutes.

(7) Most grade eight pupils could learn several symbols in the alotted time.

In order to guard against the possibly deleterious effects of students gossipping about the strange task they had to do, the pilot study and the three experimental classes were scheduled the same day.

V. THE TREATMENTS

Three teaching techniques were developed: a visual presentation technique, a visual technique supplemented with auditory practice, and a visual technique supplemented with both auditory and kinesthetic practice. These were designated treatments V, AV, and AVK, respectively. Since the purpose of the experiment was to compare the relative efficacy of the teaching techniques the total learning time was held constant no matter which teaching method was being used. The number of times each card in the set was presented, however, varied from treatment to treatment. Within each treatment, the pace of presentation was held constant from group to group. The pace used was that which kept most students working near capacity without causing undue hardship to the slower members of the group. In order to prevent the introduction of errors due to a wandering of attention, subjects were required to make an overt response, on a practice sheet, to each presentation. A set of four cards was used with each treatment.

The treatment procedures and the order of presentation of the cards in a set are summarized in Figure 4.

The problem of pace was not so easily resolved. Obviously one could not require the same number of verbal, oral and written responses. Indeed, the main advantage ascribed to oral practice is the speed with which questions can be answered and corrected. An acceptable criterion seemed to be the pace which kept most students working. The pilot study with Room 202 was used primarily to set the pace for each technique in terms of seconds per presentation.

Each teaching technique was divided into three steps requiring two minutes each. The first step consisted of two parts: a simultaneous presentation of letter and symbol, and a split presentation in which there was a five second time lag between the presentation of letter and symbol. The second step was the symbol presentation, and the third step was the letter presentation. In order to keep all subjects at the same pace, two verbal cues were used throughout the experiment. Whenever a card was presented, the experimenter said, "Look", and, whenever a correct answer was presented, the experimenter said, "Check". The procedures were varied from technique to technique in the following ways:

Step One: Familiarization

Simultaneous Presentation. This procedure was common to all three techniques. Each of the four cards in the group being used was presented flat out so that the letter and symbol were simultaneously visible for exactly five seconds. The card was then lowered

behind the screen, folded, and placed, letter up, on the desk. The folding and placement operations took about two seconds; all four cards could be shown in thirty seconds. The cards within any set were always presented in numerical order.

Split Presentation. The procedure was different for the audio-visual and audio-visual-kinesthetic techniques than for the visual technique.

In the visual technique, the folded card was held so that the symbol alone was visible for five seconds during which time the subject chose and underlined the correct letter on his practice sheet. At the end of five seconds, the experimenter said, "Check", and flipped the card and held it so that the correct answer was visible for five seconds. The folded card was then returned to the desk, symbol up, and ready, therefore, for the next presentation. This process was repeated with the following cards. The card and the particular part shown followed the same pattern across the subject groups, namely: card 1-symbol, card 2-symbol, card 1-letter, card 3-symbol, card 2-letter, card 4-symbol, card 3-letter, card 4-letter. The total time elapsed in making all eight presentations was ninety seconds.

In both the AV and the AVK teaching techniques, exactly the same procedure was followed, but with one addition. If the letter was presented, the experimenter simultaneously verbalized the question by saying, "The symbol for A was ____?". If a symbol was presented, the experimenter used a verbal check: at the same time as he showed the correct answer he would say, "The correct letter was A."

Step Two: Symbol Presentation

The procedure in step two was different for the V technique than it was for the AV or AVK techniques, but in each case there was a total of two minutes practice time.

In the V technique, the cards were shown so that the symbol was visible for three seconds. During this time, the subjects marked the appropriate symbol on their practice sheet. The card was then flipped to the check position and held for an additional three seconds while the subjects corrected their answers. Subsequent cards were presented in the same manner until all eight questions in Part II were finished. The first eight questions took one minute; the second minute was spent in random practice. The card was presented, symbol showing, and subjects asked to visualize the letter and then mark the correct letter on a list at the bottom of the practice sheet. The answer was shown immediately, and a pace of one card each three seconds was maintained with the verbal cues, "Look--Check".

In both the AV and the AVK techniques, the cards were presented so that the symbol was visible, and the subjects asked to answer aloud, in chorus, with the appropriate letter. The same order of presentation as in the V technique was used for the first eight cards, but the three seconds per card pace was maintained from the beginning. Thus, auditory practice resulted in forty pairings of letters and symbols whereas the visual practice had resulted in only twenty-eight pairings.

Step Three: Letter Presentation

The procedure in step three was different for the V and AV techniques than for the AVK technique. In both the V and AV techniques the letter was shown and the subjects marked the correct symbol on their practice sheet, as in step two. Both the letter and the check were held for three seconds during the first eight presentations, and again the last minute was spent in random practice paced at one card every three seconds. The subjects were shown the letter and asked to check the appropriate symbol in the list at the bottom of the page. A total of twenty-eight pairings of letter and symbol took place in the two minutes.

In the AVK technique, the subjects were asked to use the back of the practice sheet to draw the symbol corresponding to the letter presented. The letter was held for five seconds while the subject drew the symbol, then flipped so that the correct answer showed and held for another five seconds while the subjects checked their answers. Thus, twelve presentations could be made in the two minutes. The AVK method used in this experiment was not intended to be directly comparable to the Fernald method of teaching reading. Fernald used cursive writing to emphasize the unity of a sequence of symbols; only individual symbols were used in this experiment.

The teaching techniques and the order of presentation of cards in a set are summarized in Figure 4.

TECHNIQUES	V.	A.V.	A.V.K.
STEP ONE			
(a) Simultaneous Presentation	Whole card shown. Order: 1,2,3,4, 4 pairings 30 sec.	Whole card shown. Order: 1,2,3,4, 4 pairings 30 sec.	Whole card shown. Order: 1,2,3,4, 4 pairings 30 sec.
(b) Split Presentation	Symbol shown-- Letter marked; Then reverse. Order: 1S,2S,1L 3S,2L,4S,3L,4L 8 pairings 90 sec.	Symbol shown-- letter marked and spoken; then letter shown and spoken-- symbol marked. Order: 1S,2S,1L, 3S,2L,4S,3L,4L 8 pairings 90 sec.	Symbol shown-- letter marked and spoken; then letter shown and spoken-- symbol marked. Order: 1S,2S,1L 3S,2L,4S,3L,4L 8 pairings 90 sec.
STEP TWO	Symbol shown-- letter marked Order (first eight) 2,4,1,3,4,2,3,1 28 pairings 120 sec.	Symbol shown-- letter spoken Order (first eight) 2,4,1,3,4,2,3,1 40 pairings 120 sec.	Symbol shown-- letter spoken Order (first eight) 2,4,1,3,4,2,3,1 40 pairings 120 sec.
STEP THREE	Letter shown-- symbol marked. Order (first eight) 1,3,2,4,3,1,4,2 28 pairings 120 sec.	Letter shown-- symbol marked. Order (first eight) 1,3,2,4,3,1,4,2 28 pairings 120 sec.	Letter shown-- Symbol written. Order: 1,3,2,4,3,1,4,2,4,2,1,3 12 pairings 120 sec.
TOTALS	68 pairings 360 sec.	80 pairings 360 sec.	64 pairings 360 sec.

Figure 4. Summary of Teaching Techniques.

VI. THE EXPERIMENTAL DESIGN

For this particular experiment, only a limited number of subjects were available. Rather than reduce the number of subjects per cell for a complete factorial, it seemed advisable to use a partially balanced design. Plan 6, a Latin square for repeated measures, was used.[1]

Plan 6 is a fractional replication of a three-factor factorial experiment. Each subject in Group I is observed at all levels of factors A and B, but at only one level of factor C. There is balance with respect to the main effects of factors A and B, but no balance with respect to interactions. The assumption that interactions are negligible with respect to the main effects is restrictive, but may be checked in the analysis. Winer (1960, p. 540) says that the use of a Latin-square has much to recommend it when the primary interest is in factor B, because the Latin squares permit a more sensitive test of the main effects of factor B.

In these experiments, factor A was the set of cards used, factor B the treatments, and factor C the sequence in which the treatments were used. The designs for the experiments are summarized in Figures 5 and 6. Note that the groups were rotated for the second experiment. It was felt that this procedure might provide some check on interactions.

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[1]Winer, B. J.,.Statistical Principles in Experimental Design, (New York: McGraw-Hill, 1962), pp. 543-546.

		A_1	A_2	A_3
Group I	C_1	b_1	b_2	b_3
Group II	C_2	b_2	b_3	b_1
Group III	C_3	b_3	b_1	b_2

Figure 5. Summary of Plan 6.

		Set I Cards	Set II Cards	Set III Cards
Room 201	C_1	V	AV	AVK
Room 203	C_2	AV	AVK	V
Room 204	C_3	AVK	V	AV

Figure 6. Design for Experiment One.

		Set IV Cards	Set V Cards	Set VI Cards
Room 204	C_1	V	AV	AVK
Room 201	C_2	AV	AVK	V
Room 203	C_3	AVK	V	AV

Figure 7. Design for Experiment Two.

VII. THE CRITERION

Experiment One

The criterion for Experiment One was divided into two parts and the scores from each part analyzed separately. The first part of the test consisted of seventy-two five-item multiple choice questions. There were six questions related to each of the twelve symbols: in the three questions the symbol was given and a forced choice made among five letters, and in another three the letter was given and a forced choice made from among five symbols. The items were distributed at random over the paper. All subjects completed the test before the five-minute time limit was reached.

The second portion of the test for experiment one was of the recall type, and was given immediately after the objective test. In the recall portion of the test, students were required to draw, from memory, the appropriate symbols for the given letters.

Experiment Two

The criterion for Experiment Two was an objective test similar to that used in Experiment One. A recall test was not used in the second experiment because it was felt that learning on the objective part of the test confounded the score. For the same reason, test items were restricted to those giving a letter and requiring a choice among symbols. Consequently, the test contained only thirty-six items, three for each card.

Scoring

One mark was given for each correct answer. Keys were constructed so that the number of correct responses associated with each set of cards could be counted directly. Raw scores are tabulated in Appendix A.

CHAPTER V

THE RESULTS

A summary of the grand means for the three treatments appears in Table I. It was observed that their relative values support the general hypothesis in every case. Specifically, the grand means, from smallest to largest, followed the order V, AV, AVK in all three tests.

TABLE I

SUMMARY OF GRAND MEANS

Treatment	V	AV	AVK
Experiment One			
(a) Objective Test	16.68	17.81	19.02
(b) Recall Test	4.41	4.61	6.01
Experiment Two	7.89	8.47	8.79

Analysis of Variance

An analysis of variance was carried out for each experiment. The results of the analysis are summarized in Tables II to VII. In order to guard against violating the assumption that all pairs of observations on the same subjects have a constant correlation, the conservative test proposed by Greenhouse and Geisser was used when testing main effects.[2] However, the normal number of degrees of

[2] Ibid., p. 538.

freedom was used for testing interactions. It was decided to use an alpha = .05 for the critical ratios, but the .01 levels are also shown in the Tables in order to facilitate comparisons. The computational procedures and expected values are in Appendix B.

TABLE II

ANALYSIS OF EXPERIMENT ONE OBJECTIVE TEST

Source of Variation	SS	df	MS	F
Between Subjects	3842.25	74		
C (groups, order)	72.33	2	36.16	.58
Subjects within groups	3769.92	72	52.36	
Within subjects	1054.67	150		
A (card sets)	221.91	2	110.95	25.42*
B (treatments)	204.33	2	102.16	23.50*
Residual	.05	2	.03	.01(inter-
Error	628.38	144	4.36	action)
Critical values	$F_{.95}$ (2,144) = 3.06;		$F_{.99}$ (2,144) = 4.77	
Conservative test	$F_{.95}$ (2,72) = 3.13;		$F_{.99}$ (2,72) = 4.94	

*Significant at p = .01

Experiment One Objective Test. As Table II shows, there were no significant interactions, and no significant differences due to the main effects of factor C, which combined differences among groups and differences among sequences of treatments. The main effects of factors A and B, card sets and treatments respectively, were highly significant since both observed values of F were well above the critical value for alpha = .01 on the conservative test. A Bartlett test for the homogeneity of error variance within groups was well below significance with alpha = .05.[3] It was therefore appropriate to

[3]See Appendix B.

test for differences among treatments. The Newman Keuls method for treatment totals was used, with alpha = .01, as summarized in Table III.

TABLE III

DIFFERENCES AMONG TREATMENTS, EXPERIMENT ONE, OBJECTIVE TEST

Treatment		V	AV	AVK			
	Total	1251	1336	1426		r=2	r=3
V	1251	--	85*	175*	$q_{.99}(r,144)$	3.69	4.19
AV	1336		--	90*			
AVK	1426			--	$(\sqrt{nMS_e}\ q_{.99}(r,144)$	36.52	42.61

* Significant at p = .01

Since each of the differences were well above the critical value, it was concluded that all pairs of treatment totals were significantly different.

TABLE IV

ANALYSIS OF EXPERIMENT ONE RECALL TEST

Source of Variation	SS		df	MS	F
Between Subjects	416.58		74		
C (groups, order)		4.41	2	2.21	less than 1
Subjects within groups		412.17	72	5.72	
Within Subjects	513.67		150		
A (card sets)		18.92	2	9.64	3.57
B (treatments)		102.86	2	51.43	19.41*
Residual		10.06	2	5.03	1.90(interaction)
Error		381.83	144	2.65	
Critical values	$F_{.95}(2,144) = 3.06$;		$F_{.99}(2,144) = 4.77$		
Conservative test	$F_{.95}(2,72) = 3.13$;		$F_{.99}(2,72) = 4.94$		

* Significant at p = .01

Experiment one recall test. Table IV shows that there were no significant interactions, and no significant differences in the main effects of either factor A or factor C. Since factor B was well above significance, the Newman Keuls test was applied; with alpha = .01, as summarized in Table V.

TABLE V

DIFFERENCES AMONG TREATMENTS EXPERIMENT ONE RECALL TEST

Treatment		V	AV	AVK		r=2	r=3
	Total	341	346	451	$q_{.99}$ (r,144)	3.69	4.19
V	341	--	5	110*			
AV	346		--	105*	(nMSe) $q_{.99}$(r,144)	30.04	34.11
AVK	451			--			

*Significant at p = .01

The treatments were not all significantly different according to the results of the recall test. There was no significant difference, at alpha = .05 or .01, between the V and AV treatments. However, the AVK treatment was significantly better than either V or AV. Bartlett's test for homogeneity of error variance was well below significance at the alpha = .05 level.[4]

[4]See Appendix B.

TABLE VI

ANALYSIS OF EXPERIMENT TWO

Source of Variation	SS	df	MS	F
Between Subjects	737.46	74		
C (groups, order)	27.88	2	13.94	1.42
Subjects within groups	709.58	72	9.85	
Within Subjects	797.67	150		
A (card sets)	155.56	2	77.78	19.11*
B (treatments)	30.73	2	15.37	3.78**
Residual	24.96	2	12.48	3.07(inter-action)
Error	586.42	144	4.07	

Critical Values $F_{.95}(2,144) = 3.06$; $F_{.99}(2,144) = 4.77$

Conservative test $F_{.95}(2,72) = 3.13$; $F_{.99}(2,72) = 4.94$

*Significant at p = .01 ** Significant at p = .05

Experiment Two. In this experiment, there were significant AB interactions at the alpha = .05 level (the degrees of freedom are (2,144) for the interactions critical ratio). Although such a finding would ordinarily preclude further investigation, it was decided to proceed with the Newman Keuls comparison of individual pairs of treatments because the main effects of B had been significant. However, the results summarized in Table VII may be confounded with interactions.

The main effects of A were highly significant. Despite the possibility that these effects may have been confounded with interactions, it seemed likely that card sets 4, 5, and 6 were of significantly different levels of difficulty. As in the previous results, factor C was not significantly affecting scores.

TABLE VII

DIFFERENCES AMONG TREATMENTS EXPERIMENT TWO

Treatment		V	AV	AVK
	Total	592	635	659
V	592	--	42*	67*
AV	635		--	24
AVK	659			--

	r=2	r=3
$q_{.99}$ (r,144)	3.69	4.19
(nMS_e) $q_{.99}$(r,144)	36.52	42.61
$q_{.95}$ values	27.65	32.35

*Significant at p = .01

Although caution should be exercised in interpretation, Table VII shows that AVK and AV produced significantly better results than V in Experiment Two. However, AVK and AV were not significantly different--even at the p = .05 level. A Bartlett test for homogeneity of error variance failed to reach significance at the alpha = .05 level.[5]

Reliability. An examination of the expected values chart in Appendix B indicated that an estimate of the reliability of the tests could be obtained by using MS (subjects within groups) for MS (between people), and MS (error within) for MS (within people). The values calculated for these estimates are summarized in Table VIII. All of the coefficients are significantly greater than zero (p = .01).

TABLE VIII

ESTIMATES OF RELIABILITY

Experiment One Objective Test	r = .92
Experiment One Recall Test	r = .53
Experiment Two	r = .58

[5]See Appendix B.

The Sign Test

As was mentioned previously, there was some doubt as to the validity of the results in Experiment Two. The doubt arose because the AB interactions were significant. Winer (1962, p. 148) states that interactions are a function of the scale of measurement used, and that the experimenter is free to transform if he so desires. A second argument for using a transformation was the possibility that the test scores were something less than an interval scale. It could be argued that questions involving cards from Set 4 constitute units twenty-five per cent larger than questions on Set 6 cards. For these reasons, it was decided to use the sign test for correlated samples on the data from all three tests. If an individual's scores differed in the hypothesized direction, he was assigned a plus, if they differed in the opposite direction he was assigned a minus, and if there was no difference, a zero. Data from the raw-score tables in Appendix C is summarized in Table IX. The probabilities shown are calculated from the normal approximation to the binomial.

TABLE IX

CHANCE PROBABILITIES OF TREATMENT DIFFERENCES

Treatment Difference	AV-V	AVK-AV	AVK-V
Experiment One Objective	P = .0113	P = .0013	P = .0013
Experiment One Recall	P = .3974	P = .0013	P = .0013
Experiment Two	P = .0681	P = .2266	P = .0080

The results of the sign test, in general, supported the results of the analysis of variance. There was, however, some loss of significance. The analysis of variance for Experiment Two yielded a significant difference between AV and V treatments, while the sign test was just short of significance at the p = .05 level. This result was in line with expectations, since parametric techniques are generally more powerful than non-parametric techniques.

A further test was made of the hypothesis that the treatment effects, in rank order from smallest to largest, would be V, AV, and AVK respectively; a sign test was applied to the information in Table I, the summary of the grand means of the treatment effects of all three tests. It was observed that all differences among grand means were in the hypothesized direction. The probability that all nine differences among treatment means would be positive is .002.

TABLE X

SUMMARY OF SIGNIFICANT DIFFERENCES

Test	Analysis of Variance			Sign Test		
Experiment One Obj.	V	AV	AVK	V	AV	AVK
Experiment One Rec.	V	AV	AVK	V	AV	AVK
Experiment Two Test	V	AV	AVK	V	AV	AVK

NOTE: Treatments underscored by the same line do not differ. All other treatments differ at the .01 level.

CHAPTER VI

DISCUSSION

The results, in general, support the three specific hypotheses made at the beginning of the study. There were, however, some exceptions. For example, the visual and audio-visual techniques produced the same results on the recall test. The nature of this test--the subjects were asked to write the answer from memory--explained the results to some extent One would normally expect that visual and oral practice would be less effective than kinesthetic practice when the test required writing. However, since there was no provision for replication, the results of this portion of the test must be regarded as indicative rather than conclusive evidence.

There was fairly conclusive evidence that multisensory techniques produced more ability to recognize the symbols than monosensory techniques. However, this did not necessarily establish the addition of more sense modalities as the causative factor. The influence of at least three other elements should be investigated. Did the increase accrue: (1) from an increase in the number of pairings of letter and symbol, (2) because practice involving recall was more efficient than practice involving recognition, or (3) because varied methods produce less boredom and therefore higher motivation and more learning.

1. Pairings

Figure 3 shows a total of sixty-eight pairings of the letter and its symbol with the visual method, eighty pairings with the audio-visual method, and sixty-four pairings with the audio-visual-kinesthetic method. The increased number of pairings could account for the better scores in the audio-visual method, but by that line of reasoning, the audio-visual-kinesthetic technique would produce the lowest rather than the highest score. It is therefore safe to assume that the frequency of pairing had negligible effects in this study.

2. Relative Quality

The relative quality of recall and recognition questions during practice is not so easily assessed. It could logically be argued that the auditory practice used in step two of the AV and AVK techniques involves verbal recall and that the kinesthetic practice involves both recall and reproduction. It is probable that the recall questions involve more cortical activity than recognition questions for two reasons: first, recall questions require that all the details of construction be remembered, while recognition questions usually require only a few prominent details; and second, the motor response required in saying or writing a symbol involves the efferential nervous system in direct kinesthetic experience with the symbol. Marking an X through the correct answer involves kinesthetic experience with X, but it does not provide kinesthetic experience with the symbol itself. It therefore seems probable that the difference between recall and recognition

questions derives from the number of sense modalities which are involved. As a teaching technique, recall questions are multisensory, and any superiority of results may be attributed to that fact.

3. Motivation

The role of motivation is especially difficult to assess. It seemed quite feasible that increased variety could cause better motivation, and hence more learning in those techniques employing several types of practice. Berlyne (1960, p. 175) suggests that the modification, onset, or offset of a stimulus may bring on the orientation reaction. The orientation reaction involves physiological changes in the sense organs. For example, the pupil of the eye may dilate and therefore lower the absolute threshold for intensity of light (p. 80-81). He further states (p. 86) that learning has the major say in determining what conditions will evoke the orientation reaction as well as what will follow its evocation. In view of the arguments advanced by Berlyne, it appears that motivation could have played a major role in this experiment.

Although a definitive assessment of the effects of motivation cannot be made, the popularity of the various teaching techniques provides some basis for comparisons. The experimenter asked each student to vote, by secret ballot, for the teaching technique he liked best. Out of one hundred thirteen students in all four classes, twenty-one voted for the visual technique, twenty-eight voted for the audio-visual technique, thirty-two voted for the audio-visual-kinesthetic

technique, and thirty-two said they had no preference. The method of collecting the data was highly informal and therefore subject to gross error. However, the results did not indicate large differences in motivation.

While it was true that most subjects learned more when multi-sensory techniques were used, it was equally true that some subjects learned less. In several cases, there were extreme differences. However, there was in no instance a complete reversal of the hypothesis, that is, nine negative results. There was only one instance in which any hypothesized relationship was reversed for all three tests, namely, the AV to V relationship for student F in Room 203. A large number of cases occurred in which one of the hypothesized relationships was reversed in two out of the three tests. A summary of the subjects comparative achievement appears in Appendix D.

The intelligence scores, and school achievement records of these students were examined in an attempt to discover some pattern. It was discovered that all eleven students who achieved better by AVK methods than V methods had scored above the median on the Nelson Silent Reading Test Form A for grades six to nine. The median grade score for Wilson Junior High School grade eight students was 9.1 in September. It seemed possible there was a relationship between channel preference and reading ability. The free reading records of the eleven students showed that all of them had read more than the required one book per month, and each of them was (subjectively) classified by their literature teacher as an avid reader. There seemed

to be no relationships between school marks in other subjects or intelligence scores and reversed V-AVK order; nor was there any discoverable relationship with reversed V-AV and AV-AVK scores. In view of the fact that the reverse relationship occurred in only two out of three tests, no conclusions could be reached regarding the relationship between channel preference and academic ability.

The role of the auditory modality in this study remained a moot question. It is debatable whether the use of vocal responses, for example, were primarily auditory. Any increase in learning that oral practice brought about could be attributed to kinesthetic feedback from the vocal chords just as easily as to feedback through the auditory nerve. In addition, the audio-visual technique did not produce results that were consistently superior to those produced by visual techniques: there was no difference in scores on the recall test. Nonetheless, the significantly better scores attained by audio-visual techniques on the objective tests did support the multisensory principle.

In general, the multisensory principle received convincing support from this study. Although categoric proof is not claimed, it seems fair to conclude that multisensory teaching techniques are superior to monosensory techniques for most children.

CHAPTER VII

CONCLUSIONS AND IMPLICATIONS

The results of this study led to four general conclusions:

1. It was hypothesized that subjects would obtain significantly higher scores in tasks taught by audio-visual techniques than in tasks taught by visual techniques. In the analysis of variance, AV scores were significantly higher than V scores on the objective tests but not on the recall test (see Table X). It was therefore concluded that audio-visual techniques were more efficient than visual techniques for teaching symbol recognition. Although the possibility of inhibitory learning during the objective test precluded a definite conclusion, it seemed probable that there was little difference between visual and audio-visual techniques for teaching students to draw a symbol from memory.

2. It was hypothesized that subjects would obtain significantly higher scores in tasks taught by audio-visual-kinesthetic techniques than in tasks taught by audio-visual techniques. AVK scores were significantly higher than AV scores on both tests in Experiment One, but the scores were not significantly different in Experiment Two (see Table X). However, since the Experiment Two results were almost significant at the .05 level (see Table VII), it was concluded that audio-visual-kinesthetic techniques of teaching symbols were probably somewhat more efficient than audio-visual techniques for most students.

3. It was hypothesized that subjects would obtain significantly higher scores in tasks taught by audio-visual-kinesthetic techniques than in tasks taught by visual techniques. Since AVK scores were significantly higher than V scores on all three tests (see Table X), it was concluded that, for most students, audio-visual-kinesthetic techniques were more efficient than visual techniques for the teaching of symbols.

4. It was hypothesized that, in general, the score attained would increase with the number of sense modalities involved by the teaching technique. All the differences among means were in the hypothesized direction, as shown in Table I. Since the probability of nine positive differences occurring by chance is extremely low ($p = .002$), it was concluded that, for most subjects, the learning of symbols improved as additional sense modalities were involved by the teaching technique.

It was not the purpose of this study to present evidence supporting new and different teaching methods, but rather, to propose a theory which explained and justified practices already being used. It was felt that, if such theory could be developed, it would provide unity and cohesion in a field hitherto divided into several seemingly irreconcilable methodologies. The results of this experiment in no case contradicted the hypotheses deduced from Osgood's second principle, and gave significant support to the hypotheses in thirteen out of eighteen instances. It was therefore concluded that the results--as a whole--support Osgood's principle of spatial propinquity.

Limitations of This Study

The practical applications of the findings of an experiment are determined by the limitations imposed by the experimental procedure. The limitations of this study were a result of three factors: the task, the theory, and the experimental design.

The task. The task used in this experiment is comparable to the learning of letters of the alphabet, but not to the learning of sequences of letters or words. It is therefore not possible to generalize to all kinds of learning involved in reading.

The theory. Osgood's theory does not account for the effects of such personal factors as unwillingness to cooperate or the inability to tolerate ambiguity. The nature of the symbols used in this experiment suggests that the latter could have been an extremely important factor.

The experimental design. The latin square does not permit an analysis of interactions. In view of the significant interaction found in Experiment Two, this was a real inadequacy in the design of this experiment.

The Implications for Education

It was a primary purpose of this study to provide a learning theory rationale which could explain why certain teaching techniques produced superior results. There are four widely respected educational practices which are supported by Osgood's principle of spatial propinquity: (1) learning by doing, (2) proceeding from the concrete to the

abstract, (3) teaching reading and writing concomitantly, (4) using an eclectic approach to the teaching of reading. The first three practices stated, in effect, that learning was facilitated by direct physical experience with the task. In the classroom, this meant adding kinesthetic experience to the visual and auditory experiences provided by textbook and teacher; hence, more nervous tissue was available to the situation. A similar argument was advanced in a previous section to show that eclectic techniques for the teaching of reading owed their superiority over individual techniques to the number of sense modalities being used.

However, the findings of this study also indicated that there are some educational practices which should be changed. The widespread, and laudible, search for objective evaluation techniques has resulted in the use of multiple choice and short answer questions in school workbooks. The primary purpose of the workbook is to teach rather than to evaluate. According to the principle of multisensory learning, questions which require a child to integrate and reorganize material and then write out the answer would have two distinct advantages. First, it affords the child kinesthetic practice associated with the learning. Second, and perhaps more important, it requires integration and reorganization within the child's brain. The multiple choice question, by contrast, requires only the recognition of the best reorganization. The implication is clear: children will learn more when they are allowed to talk out and write out their classroom experiences.

The Implications for Future Research

Several areas of research are suggested by the findings of this study. It was shown, for example, that most students learn more when multisensory teaching techniques are used, but that some students appear to learn more when a monosensory technique is used. Much research is needed to clear up the relative values of the senses in learning. Are people oriented to one sense modality or another, and, if so, is the orientation learned or inherited? If a child can be shown to depend heavily on one sense modality, can the teacher concentrate on techniques relevant to that modality? Does the visually-minded child read by the look and say methods and the aurally-minded child by phonics?

Kinesthetic stimuli were found to be very effective in this study. Research should be done to show the relative values of kinesthesis, audition and vision in learning to read. Will children learn to read more quickly if they are taught with three-dimensional letters and words which they can actually manipulate?

The concept of readiness has been the basis of much controversy. According to Osgood's principle of spatial propinquity, maturation could be explained by a developmental change in the density of nervous tissue. Does the density of nervous tissue increase from babyhood to adulthood? Do all areas of the cortex grow in density? In what order?

In conclusion, it should be pointed out that the Osgood two-stage learning theory has shown great potential in unifying and ordering empirical data. Future investigators would be well advised to use it as their conceptual framework.

BIBLIOGRAPHY

Allan, M. D. (1958) "A Pattern Recognition Method of Learning Morse Code", British Journal of Psychology, 49: pp. 59-64, February, 1958.

Artley, A. S. (1953) Your Child Learns to Read, Scott Foresman.

Ash, P. and Carleton, B. (1953) "The Value of Note-taking During Film Learning", British Journal of Psychology, 23: pp. 121-125, June, 1953.

Bartley, M. (1958) Theories of Perception, New York: Harper and Bros.

Berlyne, D. E. (1960) Conflict Arousal and Curiosity, New York: McGraw Hill.

Boring, E. G (1930) "The Gestalt Psychology and the Gestalt Movement", American Journal of Psychology, 42: pp. 308-315.

Broadbent, D. E. (1956) "Listening Between and During Practiced Auditory Distractions", British Journal of Psychology, 47: pp. 51-60, February, 1956.

Broadbent, D. E. (1952) "Speaking and Listening Simultaneously", Journal of Experimental Psychology, 43: pp. 267-270.

Erazier, M. A. (editor) (1958) The Central Nervous System and Behavior, Josiah Macy Foundation Press.

Chaplin, J. P. and Krawiec, T. S. (1960) Systems and Theories of Psychology, New York: Holt Rinehard and Winston.

Child, I. L. and Wendt, G. R. (1938) "The Temporal Course of the Influence of Visual Stimulation Upon the Auditory Field", Journal of Experimental Psychology, 23: pp. 108-121.

Douglas, A. C. (1932) The Physical Mechanism of the Human Mind, Scotland: Livingstone Press.

Ewers, D. (1950) "Relations Between Auditory Abilities and Reading Abilities", Journal of Experimental Education, 18: pp. 239-262.

Ferguson, G. A. (1959) Statistical Analysis in Psychology and Education, Toronto: McGraw Hill.

Fernald, G. (1943) Remedial Techniques in Basic School Subjects, New York: McGraw Hill.

Finan, J. L. (1940) "Review of Skinner's The Behavior of Organisms", Journal of General Psychology, 22: pp. 441-447.

Forest, D. W. (1957) "Auditory Stimulation As a Determinant of Visual Threshold", American Journal of Psychology, 70: pp. 634-636.

Gaydos, H. F. (1956) "Intersensory Transfer in Discrimination of Form", American Journal of Psychology, 69: pp. 107-110.

Gray, W. S. (1948) On Their Own in Reading, Scott Foresman.

Gregg and Brogden (1952) "The Effect of Simultaneous Visual Stimulation on Absolute Auditory Sensitivity", Journal of Experimental Psychology, 43: pp. 179-186.

Guthrie, E. R. (1935) The Psychology of Learning, New York: Harper.

Hebb, D. O. (1949) The Organization of Behavior, Wiley.

Henry, S. (1947) "Children's Audiograms in Relation to Reading Attainment", Journal of Genetic Psychology, 70: pp. 211-231; and 71, pp. 3-63.

Hildreth, G. (1948) "The Interrelationships of the Language Arts", Elementary School Journal, 48: pp. 538-549.

Hilgard, E. R. (1956) Theories of Learning (second edition), New York: Appleton Century Crofts.

Hixon Symposium (1951) Cerebral Mechanisms in Behavior (edited by Jeffries, L. A.) Wiley.

Ingram, J. G. (1956) "Some Experiments on Pavlov's Theory of Suggestion", British Journal of Psychology, 47: pp. 252-258, November, 1956.

Jaffe, R. (1956) "The Influence of Visual Stimulation on Kinesthetic Figural After Effects", American Journal of Psychology, 69: pp. 70-75.

Koffka, K. (1935) Principles of Gestalt Psychology, New York: Harcourt Brace.

Kohler, W. (1927) The Mentality of Apes (Winter translation), New York: Humanities Press.

Kravkov, A. (1934) "Changes of Visual Acuity in One Eye Under Influence of the Illumination of the Other or of Acoustic Stimulation", Journal of Experimental Psychology, 17: pp. 805-812.

Mogensen, M. F. and English, H. B. (1926) "The Apparent Warmth of Colors", American Journal of Psychology, 37: pp. 427-428.

Monroe, M. (1925) "The Apparent Weight of Color and Related Phenomena", American Journal of Psychology, 36: pp. 192-206.

Nias, A. H. W. and Kay, H. (1960) "Immediate Memory of a Broadcast Feature Programme", British Journal of Psychology, 24: pp. 154-160, November, 1960.

Osgood, C. E. (1957a) "A Behavioristic Analysis of Perception and Language as Cognitive Problems", Cognition: The Colorado Symposium, Cambridge: Harvard University Press, pp. 75-118.

Osgood, C. E. (1957b) "Motivational Dynamics of Language Behavior", Nebraska Symposium on Motivational Research (Jones, M., editor).

Osgood, C. E. (1953) Method and Theory in Experimental Psychology, New York: Oxford University Press.

Postman, L. and Rosenzweig, M. (1956) "Practice and Transfer in the Visual and Auditory Recognition of Verbal Stimuli", American Journal of Psychology, 69: pp. 209-226.

Robinson, H. M. (1946) Why Pupils Fail in Reading, University of Chicago Press.

Ryan, T. A. (1940) "Interrelations of the Sensory System in Perception", Psychological Bulletin, 37: pp. 659-698.

Serrat, W. D. and Karwoski, A. (1934) "An Investigation of the Effect of Auditory Stimulation on Visual Sensitivity", Journal of Experimental Psychology, 19: pp. 604-611.

Seward, J. P. (1942) "An Experimental Study of Guthrie's Theory of Reinforcement", Journal of Experimental Psychology, 30: pp. 247-256.

Sherrington, C. (1947) Integrative Action of the Nervous System, Columbia University Press.

Skinner, B. F. (1938) The Behavior of Organisms: An Experimental Analysis, New York: Appleton Century Crofts.

Skinner, B. F. (1953) Science and Human Behavior, New York: Macmillans.

Skinner, B. F. (1954) "The Science of Learning and the Art of Teaching", Harvard Educational Review, 24: pp. 86-97.

Sperry, R. W. (1951) "Mechanisms of Neural Maturation", Chapter VII of Stevens, S., Handbook of Experimental Psychology, New York: Wiley.

Talland, G. A. (1958) "The Effect of Set on Accuracy", British Journal of Psychology, 49: pp. 117-130.

Talland, G. A. (1959) "Intersensory Perceptual Set", British Journal of Psychology, 50: pp. 231-234.

Taylor, B. (1943) "Analytic and Gestalt Approach in the Learning of Radiotelegraphic Code", American Journal of Psychology, 56: pp. 319-353.

Thorndike, E. L. (1913) The Psychology of Learning, Educational Psychology Volume II, New York: Teachers College.

Vernon, P. E. (1947) "The Film in Instruction of Adults", British Journal of Educational Research VI: pp. 149-159.

Watson, J. B. (1914) Behavior: An Introduction to Comparative Psychology, New York: Holt.

Watson, J. B. (1958) Behaviorism: College Outline Series, University of Chicago.

Winch, W. H. (1916) "Additional Researches on Learning to Spell", Journal of Educational Psychology, 7: pp. 93-110.

Winer, B. J. (1962) Statistical Principles in Experimental Design, New York: McGraw Hill.

		EXPERIMENT ONE (OBJECTIVE)				EXPERIMENT ONE (RECALL)				EXPERIMENT TWO (OBJECTIVE)			
ROOM 201 SUBJECT	I.Q.	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM
A	85	14	15	16	45	4	6	6	16	9	7	6	22
B	118	10	17	21	48	5	1	7	13	6	6	8	20
C	138	16	13	22	51	4	2	8	14	12	10	12	34
D	92	23	17	23	63	6	3	7	16	6	9	8	23
E	109	14	13	16	43	7	3	5	15	7	4	10	21
F	105	21	17	22	60	4	5	6	15	4	6	5	15
G	115	10	13	18	41	1	2	8	11	6	8	7	21
H	105	11	9	11	31	4	2	4	10	9	8	10	27
I	84	18	20	22	60	7	5	5	17	6	6	8	20
J	119	22	22	23	67	8	7	8	23	8	8	8	24
K	124	15	19	21	55	5	4	6	15	9	12	11	32
L	96	13	16	17	46	2	2	5	9	7	8	8	23
M	134	24	21	23	68	7	8	8	23	7	7	9	23
N	110	13	6	17	36	0	3	3	6	5	6	10	21
O	110	24	22	23	69	8	7	8	23	11	11	10	32
P	110	22	20	24	66	8	8	8	24	10	10	12	32
Q	117	12	13	19	44	1	2	6	9	8	10	9	27
R	116	20	20	23	63	4	4	8	16	12	11	11	34
S	112	14	16	21	51	4	4	8	16	7	9	8	24
T	130	22	21	23	66	6	3	7	16	11	12	11	34
U	102	9	13	15	37	4	4	6	14	9	11	6	26
V	122	16	17	23	56	7	4	8	19	10	9	8	27
W	104	11	12	16	39	3	2	6	11	11	9	10	30
X	128	23	23	24	70	8	7	8	23	12	12	12	36
Y	104	23	20	23	66	7	5	8	20	9	9	12	30
TOTALS	2789	420	415	506	1341	124	103	167	394	211	218	229	658
TREATMENT USED		V	AV	AVK		V	AV	AVK		AV	AVK	V	
COLUMN DIFFERENCES		2-1	3-2	3-1		2-1	3-2	3-1		2-1	2-3	1-3	
FREQUENCY +		11	25	20		6	20	18		10	11	6	
FREQUENCY -		11	0	2		14	0	2		7	10	15	
FREQUENCY 0		3	0	3		5	5	5		8	4	4	

		EXPERIMENT ONE (OBJECTIVE)				EXPERIMENT ONE (RECALL)				EXPERIMENT TWO (OBJECTIVE)			
ROOM 203 SUBJECT	I.Q.	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM
A	94	6	11	7	24	2	1	3	6	12	12	11	35
B	131	24	22	24	70	6	8	5	19	8	9	12	29
C	130	24	24	23	71	8	8	5	21	6	5	5	16
D	107	23	24	20	67	4	5	6	15	6	6	11	23
E	109	21	16	22	59	7	5	5	17	6	8	11	25
F	109	20	22	18	60	6	6	4	16	11	11	12	34
G	112	23	18	19	60	5	6	5	16	2	2	3	7
H	80	10	15	10	35	1	4	3	8	8	10	4	22
I	116	18	18	19	55	4	8	6	18	7	9	8	24
J	104	24	19	20	63	5	4	5	14	11	9	12	32
K	119	20	17	21	58	5	6	6	17	3	3	4	10
L	110	22	21	20	63	5	8	5	18	4	4	4	12
M	135	21	19	21	61	7	7	5	19	8	7	12	27
N	122	24	23	23	70	7	8	4	19	1	1	3	5
O	120	22	21	22	65	6	7	3	16	10	8	11	29
P	89	9	13	12	34	4	4	5	13	7	10	11	28
Q	117	19	20	22	61	4	8	6	18	8	5	9	22
R	100	15	11	11	37	7	5	4	16	8	11	8	27
S	98	14	14	19	47	2	4	1	7	5	8	9	22
T	129	20	20	20	60	7	6	5	18	12	11	12	35
U	100	16	15	16	47	5	5	4	14	7	9	10	26
V	103	19	20	21	60	5	6	4	15	5	8	6	19
W	120	20	21	19	60	6	4	6	16	10	9	11	30
X	105	14	16	15	45	0	5	4	9	7	9	12	28
Y	120	17	20	19	56	2	4	3	9	8	8	11	27
TOTALS	2779	465	460	463	1388	120	142	112	374	180	192	222	594
TREATMENT USED		AV	AVK	V		AV	AVK	V		AVK	V	AV	
COLUMN DIFFERENCES		2-1	2-3	1-3		2-1	2-3	1-3		1-2	3-2	1-3	
FREQUENCY +		10	10	9		14	18	12		7	18	3	
FREQUENCY -		11	12	10		6	5	9		10	5	19	
FREQUENCY 0		4	3	6		5	2	4		8	2	3	

		EXPERIMENT ONE (OBJECTIVE)				EXPERIMENT ONE (RECALL)				EXPERIMENT TWO (OBJECTIVE)			
ROOM 204 SUBJECT	I.Q.	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM	CARDS SET 1	CARDS SET 2	CARDS SET 3	SUM
A	78	16	9	17	42	6	1	3	10	2	6	7	15
B	94	14	14	14	42	4	2	5	11	9	12	10	31
C	118	14	13	19	46	8	6	5	19	9	6	12	27
D	116	21	21	21	63	7	6	7	20	6	8	10	24
E	118	21	14	16	51	5	6	7	18	9	11	8	28
F	123	24	22	23	69	8	8	8	24	7	9	12	28
G	120	15	14	21	50	3	4	3	10	6	8	10	24
H	95	16	9	17	42	4	6	5	15	6	10	11	27
I	110	16	14	21	51	5	4	3	12	8	8	8	24
J	115	24	23	24	71	8	7	7	22	10	10	12	32
K	121	15	8	14	37	4	2	3	9	4	10	12	26
L	120	19	5	12	36	3	5	5	13	5	8	12	25
M	91	22	19	20	61	6	6	4	16	10	9	12	31
N	105	20	18	20	58	5	2	4	11	8	7	10	25
O	129	24	22	23	69	8	5	6	19	10	10	12	32
P	129	24	22	24	70	7	5	6	18	6	8	12	26
Q	100	18	12	14	44	5	5	5	15	4	4	8	16
R	130	23	20	23	66	8	8	8	24	9	7	10	26
S	114	8	8	8	24	1	1	1	3	4	5	8	17
T	112	18	17	18	53	5	3	3	11	7	11	12	30
U	104	21	12	19	52	5	3	7	15	4	7	9	20
V	98	10	8	6	24	6	0	2	8	8	6	9	23
W	109	20	15	20	55	7	2	4	13	6	10	12	28
X	102	18	12	20	50	7	3	6	16	5	6	12	23
Y	132	19	17	22	58	7	5	6	18	9	6	11	26
TOTALS	2783	460	368	456	1284	142	105	123	370	171	202	261	634
TREATMENT USED		AVK	V	AV		AVK	V	AV		V	AV	AVK	
COLUMN DIFFERENCES		1-2	3-2	1-3		1-2	3-2	1-3		2-1	3-2	3-1	
FREQUENCY +		21	21	9		16	13	14		15	22	23	
FREQUENCY -		1	1	8		4	5	5		6	2	1	
FREQUENCY 0		3	3	8		5	7	6		4	1	1	

APPENDIX B

COMPUTATION PROCEDURES FOR LATIN-SQUARE PLAN 6

1. Summary Tables

General Form

	a_1	a_2	a_3	
G_1 c_1	b_1	b_2	b_3	C_1
G_2 c_2	b_2	b_3	b_1	C_2
G_3 c_3	b_3	b_1	b_2	C_3
	A_1 B_1	A_2 B_2	A_3 B_3	G

$B_1 = b_1 + b_1 + b_1$

$G = \Sigma B = \Sigma C = \Sigma A$

Exp. I(a) Obj.

	a_1	a_2	a_3	
Rm.201 C_1	420	415	506	C_1=1341
Rm.203 C_2	465	460	463	C_2=1388
Rm.204 C_3	460	368	456	C_3=1284
	A_1=1345	A_2=1243	A_3=1425	G=4013
	B_1=1251	B_2=1336	B_3=1426	

Exp. I(b) Recall

	a_1	a_2	a_3	
Rm.201 C_1	124	103	167	C_1=394
Rm.203 C_2	120	142	112	C_2=374
Rm.204 C_3	142	105	123	C_3=370
	A_1=386	A_2=350	A_3=402	G=1138
	B_1=341	B_2=346	B_3=451	

Exp. II

	a_1	a_2	a_3	
Rm.201 C_1	171	202	261	C_1=634
Rm.203 C_2	211	218	229	C_2=658
Rm.204 C_3	180	192	222	C_3=594
	A_1=562	A_2=612	A_3=712	G=1886
	B_1=592	B_2=635	B_3=659	

HOMOGENEITY OF VARIANCE

S^2 for $G_k = \Sigma x_k^2 - \frac{P_k^2}{n}$

Within Group Variance

Room	201	203	204
Exp.I(a)	1374.56	1382.24	1641.60
Exp.I(b)	289.04	217.68	287.28
Exp. II	338.56	662.08	295.36

Exp. I(a) F(max) = 1.19
Exp. I(b) F(max) = 1.33
Exp. II F(max) = 2.24

Critical Value

$F(max)_{.95}(3,24) = 2.73$

Conclusion: Error variance is homogeneous within groups.

APPENDIX B

COMPUTATION (Continued)

Formula	Exp. I(a)	Exp. I(b)	Exp. II
(1) $\frac{G}{n\ p^2}$	71,574.08	5,755.75	15,808.87
(2) Sum X^2	76,471.00	6,686	17,344
(3) $\frac{A_1^2 + A_2^2 + A_3^2}{n\ p}$	71,795.99	5,774.67	15,964.43
(4) $\frac{B_1^2 + B_2^2 + B_3^2}{n\ p}$	71,778.31	5,858.61	15,839.60
(5) $\frac{C_1^2 + C_2^2 + C_3^2}{n\ p}$	71,646.41	5,760.16	15,836.75
(6) $\frac{\text{Sum (cell total)}^2}{n}$	72,072.60	5,892	16,048
(7) $\frac{\text{Sum } P^2}{p}$	75,416.33	6,172.33	16,546.33

Note X^2 is the square of each individual measurement.
P^2 is the square of the sum of all measurements taken on an individual.

Source S^2	Formula	Exp. I(a)	Exp.I(b)	Exp. II
Between Subjects	(7)-(1)	3842.75	416.58	737.46
C (order)	(5)-(1)	72.33	4.41	27.88
Subj. w. groups	(7)-(5)	3769.92	412.17	709.58
Within Subjects	(2)-(7)	1054.67	513.67	797.67
A	(3)-(1)	221.91	18.92	155.56
B	(4)-(1)	204.33	102.86	30.73
Residual	(6)+2(1)-(3)-(4)-(5)	.05	10.06	24.96
Error	(2)+(5)-(6)-(7)	628.38	381.83	586.42

NOTE For general formulae for degrees of freedom see Winer (1962) Table 10.7-3, p. 544.

APPENDIX C

COMPUTATION OF SIGN TEST RESULTS

Test	Difference	+	-	Dev.	S^2	Dev/S	Z	Proba-bility
Experiment I Objective Test	AV-V	41	22	9.0	63/2	18/7.94	2.28	.0113
	AVK-AV	44	19	12.0	63/2	24/7.94	3.02	.0013
	AVK-V	51	15	12.5	66/2	25/8.12	3.08	.0013
Experiment I Recall Test	AV-V	31	28	1.0	59/2	2/7.68	.26	.3974
	AVK-AV	48	11	18.0	59/2	36/7.68	4.69	.0013
	AVK-V	52	11	20.0	63/2	40/7.94	5.04	.0013
Experiment Two Test	AV-V	39	26	6.0	65/2	12/8.06	1.49	.0681
	AVK-AV	35	28	3.0	63/2	6/7.94	.76	.2266
	AVK-V	41	21	9.5	62/2	19/7.87	2.41	.0080

N.B. Values of the above summations are obtained by adding the respective difference frequencies of plus and minus signs from the bottom of Appendix B tables.

	AV - V		AVK - AV		AVK - V	
	f plus	f minus	f plus	f minus	f plus	f minus
201 Experiment I Obj.	11	11	25	0	20	2
203 Experiment I Obj.	9	10	10	11	10	12
204 Experiment I Obj.	21	1	9	8	21	1
TOTALS	41	22	44	19	51	15
201 Experiment I Recall	6	14	20	0	18	2
203 Experiment I Recall	12	9	14	6	18	5
204 Experiment I Recall	13	5	14	5	16	4
TOTALS	31	28	48	11	52	11
201 Experiment II	6	15	10	7	11	10
203 Experiment II	18	5	3	19	7	10
204 Experiment II	15	6	22	2	23	1
TOTALS	39	26	35	28	41	21

Room 201 Subject	I.Q.	EXPERIMENT Ia AV-V	EXPERIMENT Ia AVK-AV	EXPERIMENT Ia AVK-V	EXPERIMENT Ib AV-V	EXPERIMENT Ib AVK-AV	EXPERIMENT Ib AVK-V	EXPERIMENT II AV-V	EXPERIMENT II AVK-AV	EXPERIMENT II AVK-V
A	85	+	+	+	+	0	+	+	-	+
B	118	+	+	+	-	+	+	-	0	-
C	138	-	+	+	-	+	+	0	-	-
D	92	-	+	0	-	+	+	-	+	+
E	109	-	+	+	-	+	-	-	-	-
F	105	-	+	+	+	+	+	-	+	+
G	115	+	+	+	+	+	+	-	+	+
H	105	-	+	0	-	+	0	-	-	-
I	84	+	+	+	-	0	-	-	0	-
J	119	0	+	+	-	+	0	0	0	0
K	124	+	+	+	-	+	+	-	+	+
L	96	+	+	+	0	+	+	-	+	0
M	134	-	+	-	+	0	+	-	0	-
N	110	-	+	+	+	0	+	-	+	-
O	110	-	+	-	-	+	0	+	0	+
P	110	-	+	+	0	0	0	-	0	-
Q	117	+	+	+	+	+	+	-	+	+
R	116	0	+	+	0	+	+	+	-	0
S	112	+	+	+	0	+	+	-	+	+
T	130	-	+	+	-	+	+	0	+	+
U	102	+	+	+	0	+	+	+	+	+
V	122	+	+	+	-	+	+	+	-	+
W	104	+	+	+	-	+	+	+	-	-
X	128	0	+	+	-	+	0	0	0	0
Y	104	-	+	0	-	+	+	-	0	-
FREQUENCY +		11	25	20	6	20	18	6	10	11
FREQUENCY -		11	0	2	14	0	2	15	7	10
FREQUENCY 0		3	0	3	5	5	5	4	8	4

Room 204		EXPERIMENT Ia			EXPERIMENT Ib			EXPERIMENT II		
Subject	I.Q.	AV-V	AVK-AV	AVK-V	AV-V	AVK-AV	AVK-V	AV-V	AVK-AV	AVK-V
A	78	+	−	+	+	+	+	+	+	+
B	94	0	0	0	+	−	+	+	−	+
C	118	+	−	+	−	+	+	−	+	+
D	116	0	0	0	+	0	+	+	+	+
E	118	+	+	+	+	−	−	+	−	−
F	123	+	+	+	0	0	0	+	+	+
G	120	+	−	+	−	0	−	+	+	+
H	95	+	−	+	−	−	−	+	+	+
I	110	+	−	+	−	+	+	0	0	0
J	115	+	−	+	0	+	+	0	+	+
K	121	+	+	+	+	+	+	+	+	+
L	120	+	+	+	0	−	−	+	+	+
M	91	+	+	+	−	+	0	−	+	+
N	105	+	0	+	+	+	+	−	+	+
O	129	+	+	+	+	+	+	0	+	+
P	129	+	0	+	+	+	+	+	+	+
Q	100	+	+	+	0	0	0	0	+	+
R	130	+	0	+	0	0	0	−	+	+
S	114	0	0	0	0	0	0	+	+	+
T	112	+	0	+	0	+	+	+	+	+
U	104	+	+	+	+	−	+	+	+	+
V	98	−	+	+	+	+	+	−	+	+
W	109	+	0	+	+	+	+	+	+	+
X	102	+	−	−	+	+	+	+	+	+
Y	132	+	−	+	+	+	+	−	+	+
FREQUENCY +		21	9	21	13	14	16	15	22	23
FREQUENCY −		1	8	1	5	5	4	6	2	1
FREQUENCY 0		3	8	3	7	6	5	4	1	1

Room 203 Subject	I.Q.	EXPERIMENT Ia AV-V	EXPERIMENT Ia AVK-AV	EXPERIMENT Ia AVK-V	EXPERIMENT Ib AV-V	EXPERIMENT Ib AVK-AV	EXPERIMENT Ib AVK-V	EXPERIMENT II AV-V	EXPERIMENT II AVK-AV	EXPERIMENT II AVK-V
A	94	−	+	+	−	−	−	−	+	0
B	131	0	−	−	+	+	+	+	−	−
C	130	+	0	+	+	0	+	0	+	+
D	107	+	+	+	−	+	−	+	−	0
E	109	−	−	−	+	−	0	+	−	−
F	109	+	+	+	+	0	+	+	−	0
G	112	+	−	−	0	+	+	+	−	0
H	80	0	+	+	−	+	+	−	+	−
I	116	−	0	−	−	+	+	−	−	−
J	104	+	−	−	0	−	−	+	−	+
K	119	−	−	−	−	+	0	+	−	0
L	110	+	−	+	0	+	+	0	0	0
M	135	0	−	−	+	0	+	+	−	+
N	122	+	−	0	+	+	+	+	−	0
O	120	0	−	−	+	+	+	+	−	+
P	89	−	+	+	−	0	−	+	−	−
Q	117	−	+	−	−	+	+	+	−	+
R	100	+	−	0	+	−	+	−	0	−
S	98	−	0	−	+	+	+	+	−	−
T	129	0	0	0	+	−	+	+	0	+
U	100	0	−	−	+	0	+	+	−	−
V	103	−	+	−	+	+	+	−	−	−
W	120	+	+	+	0	−	−	+	−	+
X	105	−	+	+	−	+	+	+	−	−
Y	120	−	+	+	−	+	+	+	−	0
FREQUENCY +		9	10	10	12	14	18	18	3	7
FREQUENCY −		10	11	12	9	6	5	5	19	10
FREQUENCY 0		6	4	3	4	5	2	2	3	8

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